Environmental assessment of low- energy social housing

Boatemah Walk building, Brixton

by

Lidia Johansen Vargas

The Bartlett School of Graduate Studies

University College London

A dissertation submitted in part fulfilment of the degree of Master of Science Built Environment: Environmental Design and Engineering

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ABSTRACT

Energy use from buildings represents a considerable share from the UK energy consumption as a whole and the resulting CO_2 emissions are considered the main driver for climate change. There is a global urge for new and existing buildings to be truly effective in reducing their energy consumption.

This study evaluates the performance in use of low energy design in social housing: Boatemah Walk is a newly built residential block of 18 flats located in Angell Town, Brixton, which benefits from various low energy enhancing features such as: a low embodied energy building fabric, super insulation, photovoltaic panels integrated in the roof, rainwater recycling system and non-toxic building materials and finishes. The new building layout and surrounding landscape influences positively the community integration and safety.

The evaluation has been done through observation, monitoring, interviews with tenants and the use of TAS software, throughout the year after occupation. Boatemah Walk building has proved successful in some aspects and less successful in others.

It is crucial that a demonstration project like Boatemah Walk building considers all mechanisms necessary to monitor its efficiency, as this would provide feedback to prove the efficiency and encourage similar investments. However, during the course of the study it was found that a meter for the recycled water and export meters for the photovoltaic production were missing. This proved to be an obstacle for the accurate monitoring of the building performance.

The annual heating in Boatemah Walk is below the national averages, which confirms the good performance of its building fabric. In hot summer days the lightweight building is expectedly vulnerable to the outside. This is not a frequent occurrence; however the effects of climate change are very likely to increase the length and temperatures in the future.

The tenants' energy consuming behavior has a definitive impact, as revealed through monitoring and direct interviews. There is a wide difference between tenants in terms of their environmental concern and attitudes, which is reflected in the overall performance of the building.

One of the most successful aspects of this development is probably the effect it is having in the community. The tenants are highly satisfied with the building in various aspects, and the ones who used to live in Angell Town before the regeneration have experienced a very positive change in their quality of life and a sense of pride about their community.

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My special thanks to my parents and husband who gave me their continuous support and encouragement throughout this study.

1. Introduction

1.1. Carbon dioxide emissions and climate change

"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."[1]

Climate change or variability can occur as a result of natural forces in the climate system, for example variations in the strength of the incoming solar radiation, volcanic eruptions, and changing patterns in atmospheric and oceanic circulation. Any human induced changes will be embedded into this natural flow of climate events.

There has been a global debate around the question: "Is climate change a result of the planet's natural evolution or is human activity disrupting the direction of natural forces?" Many hundreds of scientists from several countries participated in the preparation of the Third Assessment Report of the Intergovernmental Panel on Climate Change to give an answer to this and many other questions. The scientific community strongly agree that greenhouse gases resulting of human activity are influencing the natural process of climate change, primarily carbon dioxide emissions.

Human activity produces considerable concentrations of carbon dioxide, accounting for approximately 85%, and less amount of methane and nitrous oxide among other gases. Carbon dioxide is released into the atmosphere whenever a fossil fuel is burnt to extract energy. It absorbs infrared radiation emitted from the Earth's surface, causing a warming in the lower atmosphere. Concentrations of Carbon dioxide have been measured on the Peak of Mauna Loa Mountain in Hawaii since 1958 as can be seen in figure 1[2].

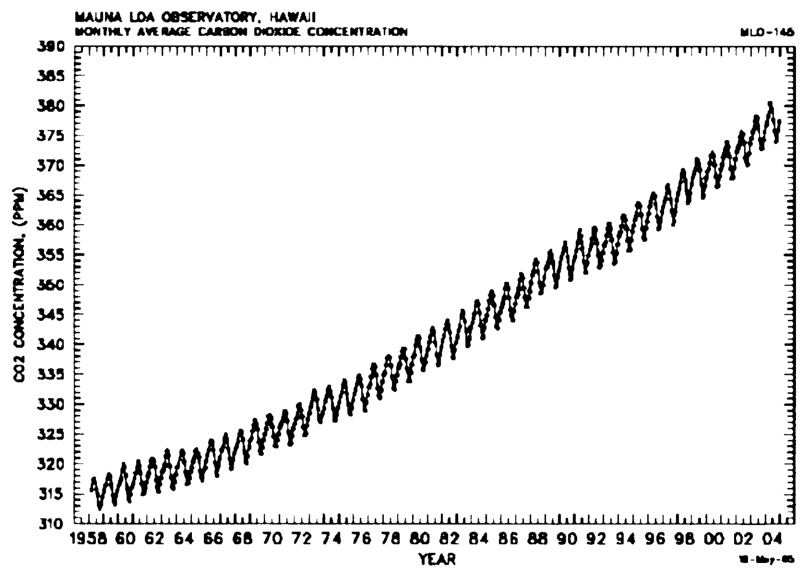


Figure 1: Carbon Dioxide concentrations in the atmosphere: Mauna Loa Curve [2]

The measurements are taken at this site as it is far away from sources of pollution. This trend clearly shows an increase in concentrations from 316 to 369 ppm (parts per million) since 1958.

Figure 2 shows the variations on the earth surface temperature for the past 140 years. The data comes from thermometers. The red bars show the temperature year by year, the black line is an annual curve suppressing fluctuations.

Figure 3 shows the variations on the earth surface temperature for the past 1000 years. The data after 1860 comes from thermometers (shown in red); prior to this year data has been gathered from historical records, tree rings, corals and ice cores.

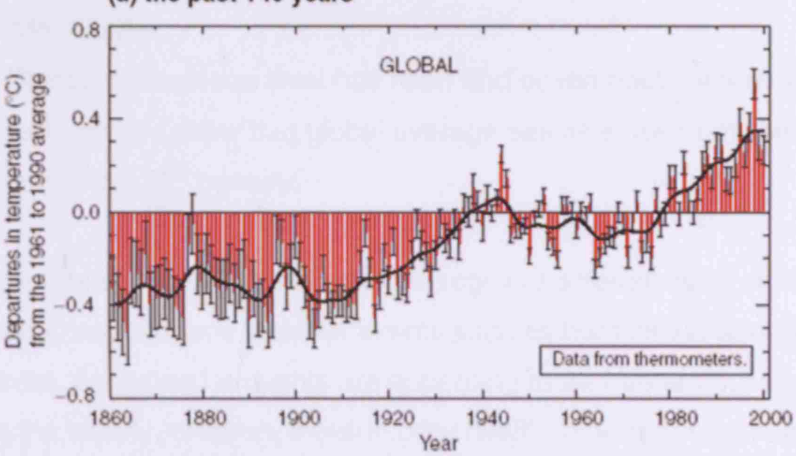


Figure 2: Variations on the Earth's surface temperature for the past 40 years [1]

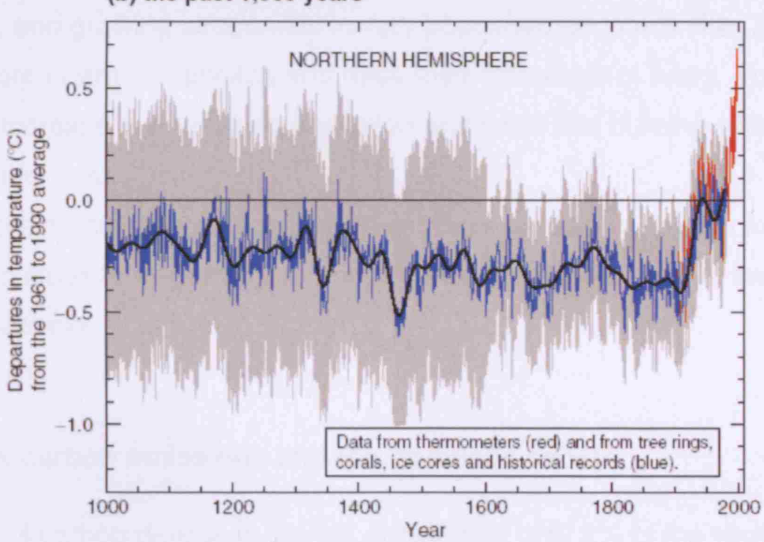


Figure 3: Variations on the Earth's surface temperature for the past 1000 years [1]

The effects of this rise in greenhouse gas concentrations have altered the composition of the global atmosphere and is clearly affecting the climate system as shown by scientific observations. The following are some of the statements published as a result of a rigorous scientific analysis:

- The global average surface temperature has increased over the 20^{th} century by about 0.6° C.
- Globally it is very likely (90 to 99% certain) that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record, since 1861.
- Satellite data show that there are very likely (90 to 99% certain) to have been decreases of about 10% in the extent of the snow cover and ice extent since the late 1960's.
- Global average sea level has risen and ocean heat content has increased.
- Tide gauges show that global average sea level rose between 0.1 and 0.2 metres during the 20^{th} century.

These climate alterations; an increase in regional differences in warming patterns, precipitation and extreme weather events such as hurricanes, tornadoes, thunderstorms, heat waves, floods and droughts are appearing more frequently. Vulnerable populations such as the elderly, children, those in poor health, or those living in poor quality housing will be most affected by stresses related to weather extremes.

Developed and industrialised countries are responsible for most of the world emissions nowadays, and growing economies in very populated countries like China and India are in need of more energy to develop and raise their standards of living. This is expected to lead to an increase in energy consumption and fossil fuel burning with a high environmental cost.
It is therefore crucial, that a global effort is made, particularly by the most technologically advanced nations to invest in research for renewable technologies and ensure more sustainable living.

1.2. UK carbon emissions and the domestic sector

Emissions of carbon dioxide in the UK account for only 2% of the world total.[3] Therefore any significant impact on cutting carbon emissions would only be achieved by global commitment. The Kyoto Protocol, ratified by the EU and its member states in May 2002, is an example of common efforts to combat climate change. The Kyoto Protocol is a legally binding international agreement, under which the developed countries have committed themselves to reduce their emissions of greenhouse gases.

Under the Protocol, the UK government has committed to reduce the emission of six greenhouse gases (CO_2, CH_4, N_2O, NFCs, PFCs and SF_6) by 12.5% over the period 2008-12. Cuts in the three most important gases – carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_20) - will be measured against a base year of 1990. Cuts in the other three long-lived industrial gases can be measured against either a 1900 or 1995 baseline. In addition, the UK has committed to a national target or reducing its carbon dioxide emissions by 60% of 1990 levels by 2050.

In the last 30 years the levels of carbon emissions in the UK seem to have decreased as can be seen in Figure 4[4]. The industry and residential sectors' contributions are decreasing permanently over the time span, the services sector has remained the same, while the transport sector is the only one to show an increase.

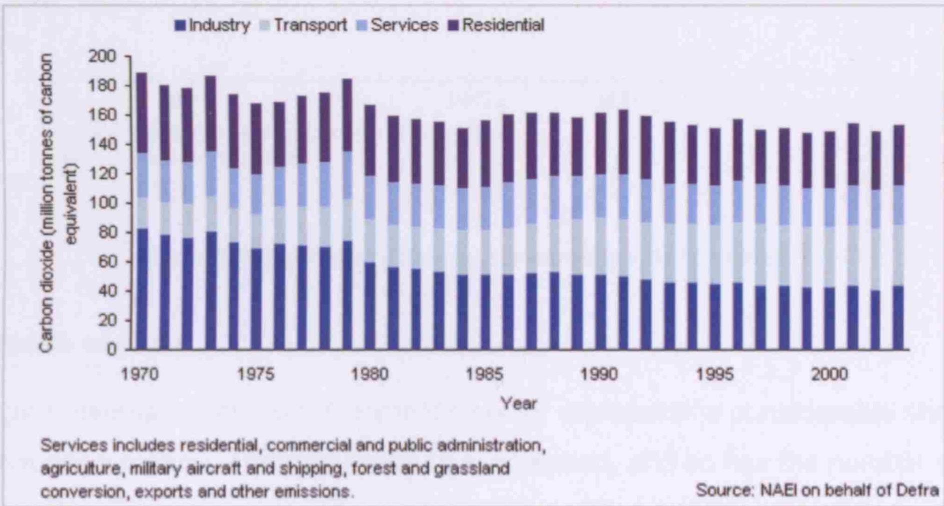


Figure 4: Carbon Dioxide emissions by end-user in the UK, 1970 to 2003 [4]

However, at the same time energy consumption has increased steadily since the 1980s as can be seen in Figure 5[5]. There is no direct proportion between the energy consumed and the carbon emissions produced mainly because of efficiency improvements to the supply of energy, reduction in losses involved in conversion, transmission and distribution as well as the composition of the fuel mix.

The fuel mix has changed considerably since 1970 as natural gas consumption has risen and coal consumption has decreased. Natural gas is a much 'cleaner' fuel, resulting in less carbon emissions when burning, compared to solid fuels. Even though these changes have brought successful results in terms of reducing carbon emissions to date, this trend will reverse if the fossil fuel- dependent consumption increases. And most importantly, it must be considered that these fossil fuels are resources in depletion, and it is not possible to rely on their availability in the next decades. The shift towards renewables has to be rapid if the targets set by the government under the Kyoto Protocol agreement are to be met.

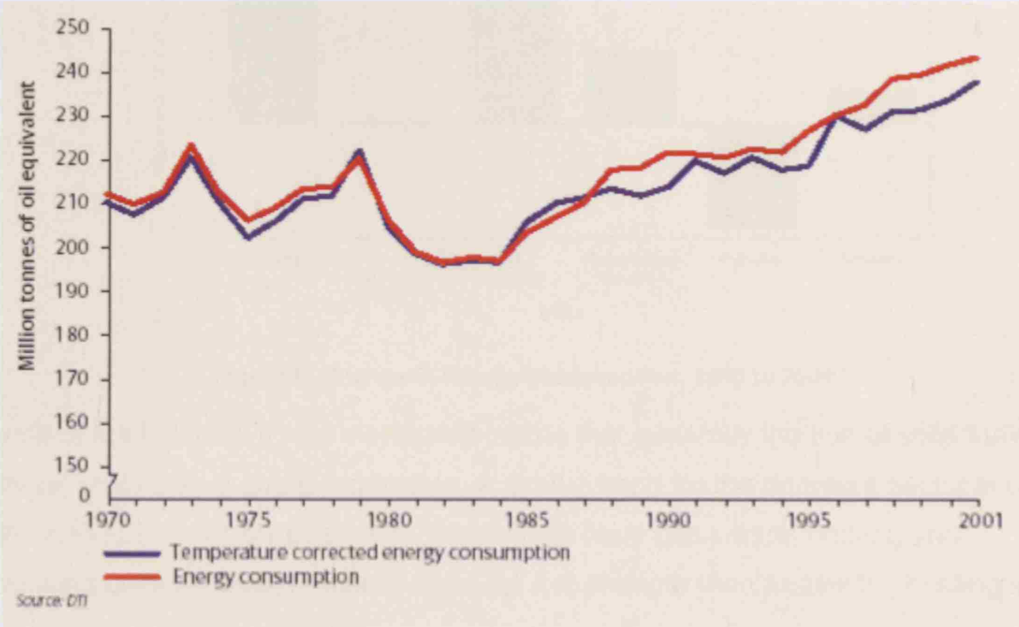


Figure 5: Total Primary Energy consumption, 1970 to 2001 [5]

The domestic sector

The energy consumption of the UK domestic sector represents a considerable share of the national consumption. The population has increased, and so has the number of households, the disposable income per household and the number of appliances that are used on a daily basis. The size of the average household has decreased, with more people living alone every year. The proportion of one-person households has almost doubled since 1971, partly due to the increase in the life expectancy since the 1970's. By the year 2000, 50 per cent of those aged 75 and over lived alone. The smaller the household, the greater the amount of energy consumed per person.

The type and age of housing also has an impact on energy consumption. Smaller flats consume less for space heating than detached houses, for example, due to lower exposed surface to internal volume ratio. In 1996 only 19 per cent of dwellings in England were flats. Newer houses have to comply with much higher energy efficiency standards, while the older housing stock (40% of which was built before 1945) is still in the process of improving its building fabric standards to comply with Part L of the Building Regulations standards[6]. Domestic energy consumption is growing at a higher speed than UK consumption as a whole. Figure 6 shows the change in energy consumption by every sector from 1990 to 2004. The domestic sector is rising and has experienced a considerable increase in the last 10 years.

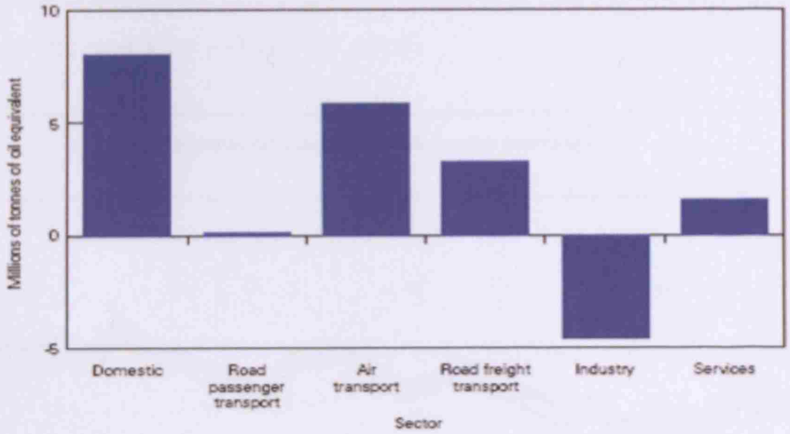


Figure 6: Change in energy consumption, 1990 to 2004 [5]

In terms of the fuel mix, it was mentioned before that generally the use of solid fuels is declining, while that of gas is increasing. A similar trend for the domestic sector is clearly shown in Figure 7[7]. Every year more households have gas central heating and condensing boilers installed, mainly because it is cheaper than an electric heating system and more efficient than solid fuel.

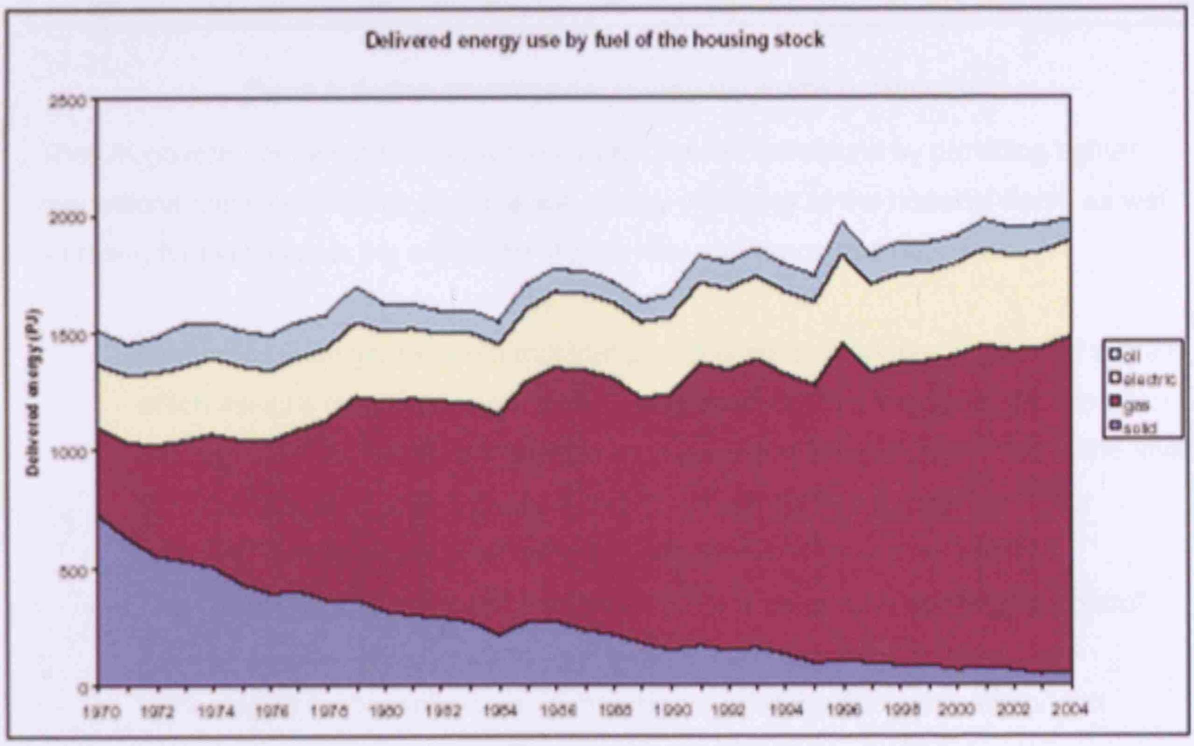


Figure 7: Delivered energy use by fuel of the housing stock [7]

The effect of this can be seen in the decrease of overall carbon emissions (figure 8), as the burning of gas results in less emissions per unit than any other fossil fuel. The electricity, however, proves to be the most intense form of energy. In the UK, the contribution from hydro, renewables and other types of clean electricity production is very low. Most electricity comes from burning fossil fuels, and therefore it produces more carbon emissions per unit than either coal or oil.

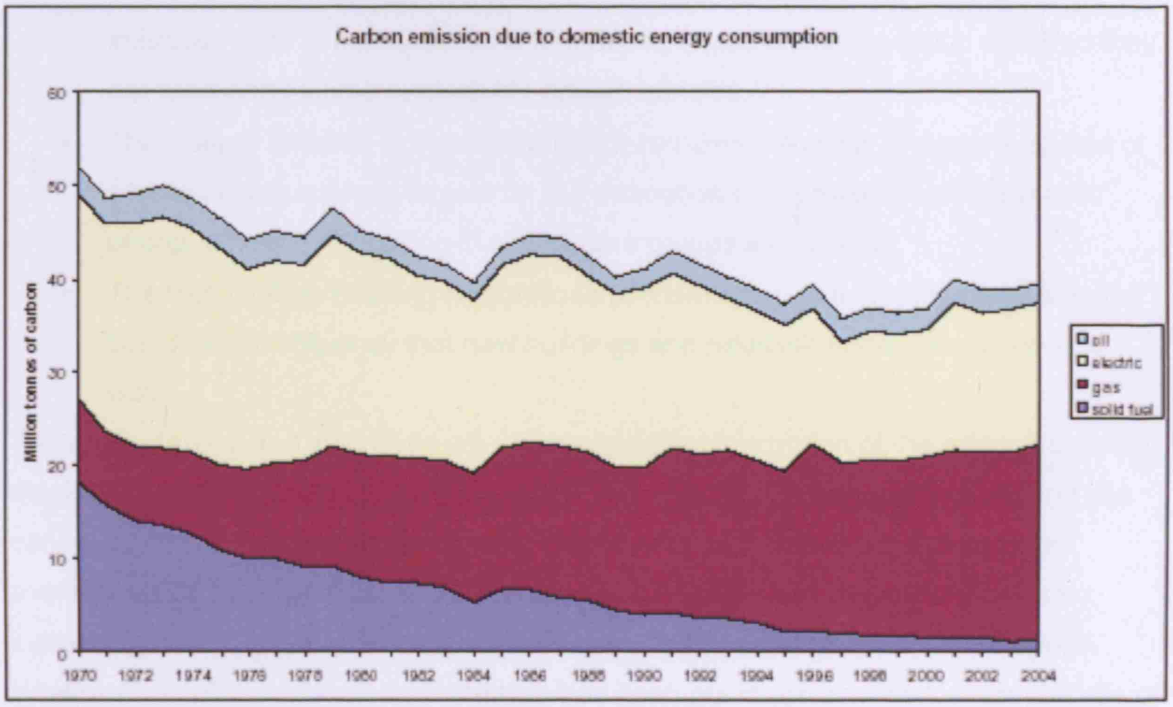


Figure 8: Carbon emissions due to domestic energy consumption[7]

The UK government aims to reduce the carbon dioxide emissions by providing tighter regulations and incentives to upgrade the energy efficiency of the housing stock, as well as rating tools to assess the efficiency of both new and renovated houses.

- Ecohomes is an assessment tool that provides an environmental labelling system, which assigns credits in seven broad categories: energy, transport, pollution, land use and ecology, health and wellbeing, materials and water, according to the level of performance achieved. Every category is then applied a weighing factor reflecting its relative importance to achieve an overall score out of 100.[8]
- The Department of Trade and Industry's (DTI) "Low carbon buildings program" managed by the energy saving trust provides grants for micro generation technologies for householders, communities, schools, the public sector and businesses, replacing Clear Skies and Solar PV programs. The grant covers technologies such as: Solar photovoltaics, wind turbines, small hydro, solar

thermal hot water, heat pumps, bio energy, combined heat and power (CHP) and fuel cells.[9]

- The Home Energy Conservation Act (HECA) requires all UK local authorities with housing responsibilities to prepare a report on practicable and cost effective measures to improve the energy efficiency of their housing stock, and report on the progress on implementation.[10]
- The Warm Front scheme provides financing for insulation and heating improvements to homeowners and those in rented accommodation provided they are receiving income or disability-related benefits.[11]
- The Energy Efficient Commitment (EEC) requires electricity and gas suppliers of certain size to achieve targets for the promotion of improvements in domestic energy efficiency, focusing in low-income groups as a priority.[12]
- The Part L of the Building Regulations (Conservation of fuel and power) sets the standards of efficiency that new buildings and refurbishments need to comply with.[6]

These regulations and incentives are encouraging the renovation of the existing building stock, especially in terms of cavity insulation, loft insulation, window standards and gas central heating systems with condensing boilers. Figure 9 shows that the weighted average space heating efficiencies for each type of tenure and the whole stock are increasing, which is partly due to the increase in central heating system installations. However no policy, legislation or incentive has been put in place to discourage the use of non-renewable resources and energy sources.

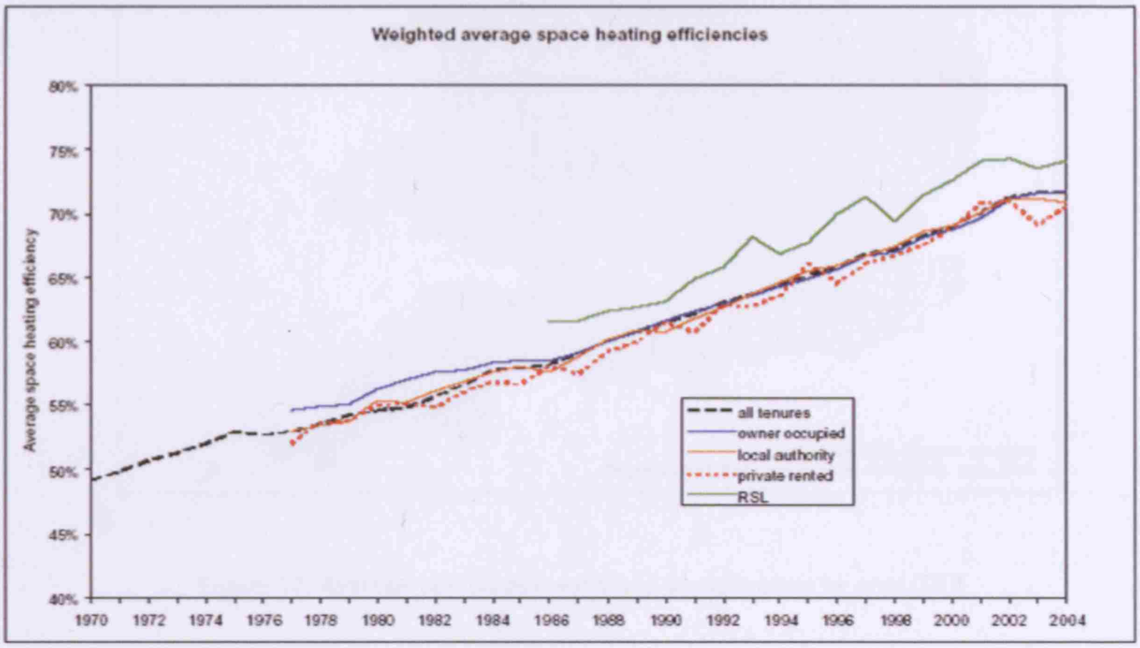


Figure 9: Weighted average space heating efficiencies [7]

The figure below shows the UK average annual domestic gas consumption per households measured in 2003, which fluctuates between 18,000 and 22,000 kWh.
It is evident that northern regions tend to consume more gas, mainly due to space heating requirements.

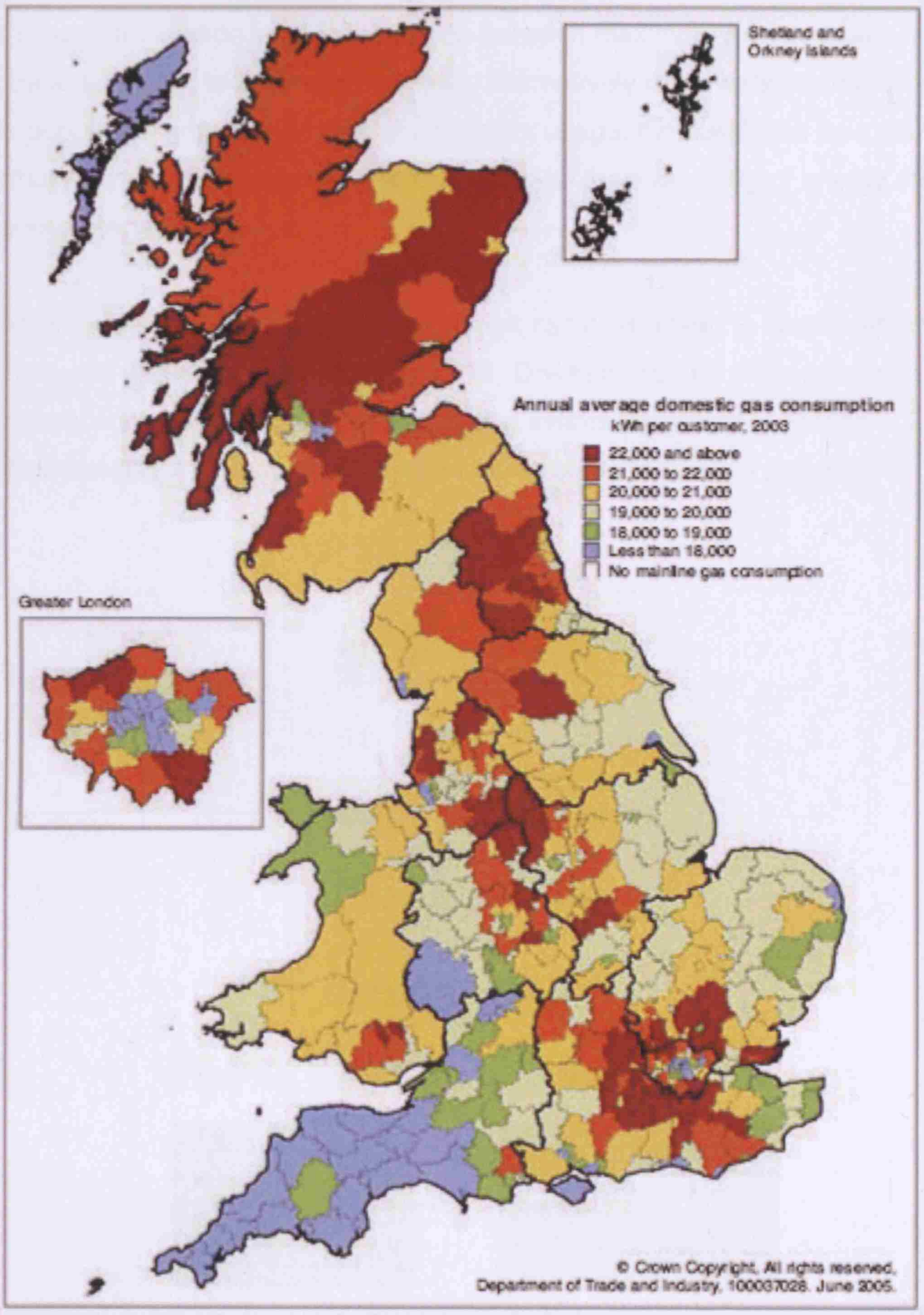


Figure 10: Average annual domestic gas consumption by area (DTI)

1.3. Water supply – shortages and flooding

Water supply has been a growing concern for specialists in order to meet consumer demands. Before coming through the tap, it has to be extracted from a natural water body, stored in a reservoir and conveyed to the water works where it is treated and finally distributed to dwellers. If the water source diminishes its yield, or if the yield remains the same but seasonal variation broadens the gap between maximum and minimum flows, there will be a disruption to the normal supply. Alternatively if the water demand increases along with population growth or a greater per capita usage, there will also be a disruption to the normal supply. Water supply will also depend on the availability of energy, needed though various stages of the process.

Global warming is likely to speed up the hydrologic cycle, and lead to increased incidence of both floods and droughts, as seen in figure 11. Owing to climate alterations occurring more frequently such as the droughts and flooding events described in section 1.1, appropriate measures are likely to be taken in the future to tackle this problem.

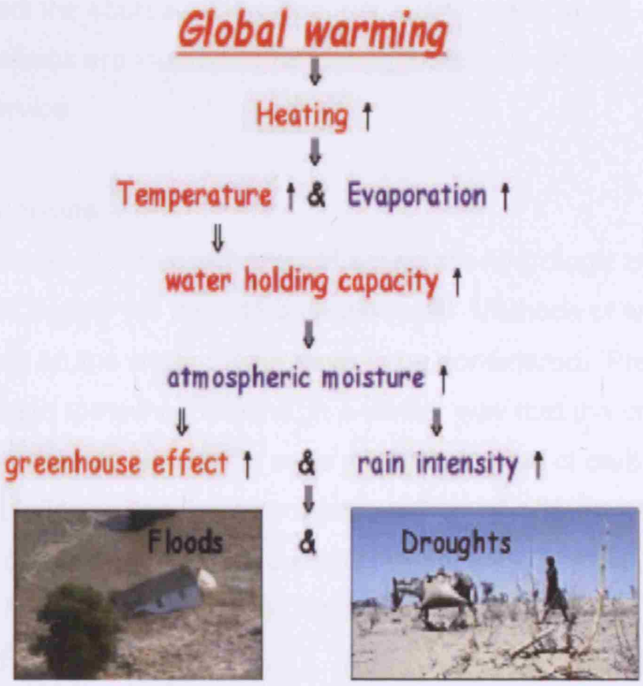


Figure 11- Global warming is likely to speed up the global hydrologic cycle[13]

- **Droughts**

The scarcity of water during summer season is becoming more intense. Also its counterpart, the winter drought, appears to be increasing accordingly. If the problem develops into a continual shortage of water, there will be the need to improve the infrastructure of water conveyance, storage, treatment and distribution.[13]
Lack of sufficient water is caused not only by droughts - if there is not the right amount of volume of water storage there will also be shortage. At certain periods of the year, demand is supplied solely by water accumulated in reservoirs, not by the incoming natural flows. Therefore if there is not enough water impounded, there will be shortages. One of the problems affecting reservoirs is that incoming sediments are increasing at a rate of 3% per 20 years[14], thus diminishing their storage capacity (see figure 12). More reservoirs will have to be constructed, or improvements made to the existing ones in the following years.

- **Flooding**

The increased water volumes in rivers, streams and lakes are beneficial to the population up to a limit. Above a certain level of flow, run off of superficial waters becomes a nuisance or even a perilous occurrence.
Floods affect not only households near to rivers or in the sphere of influence of floodable terrain, it can also affect the source of services, because if waterworks, electric power plants or any other facilities are inundated rendering them useless, it will also affect their respective areas of service.

- **Building regulations**

Many of the consequences of climate change affecting the hydrologic cycle and consequently the water supply will have to be confronted. Methods of water storage in buildings not depending on the water mains have to be considered. Present regulations will have to accommodate to new conditions, in a similar way that the changes to the regulations on energy conservation aim to save a million tonnes of carbon per year. Likewise, building regulations intending to enhance the water offered to the residents will evolve from research and studies that are currently under way, or studies which shall be initiated in the future. There is also room for regulations at council level such as hosepipe ban for gardening and other uses.

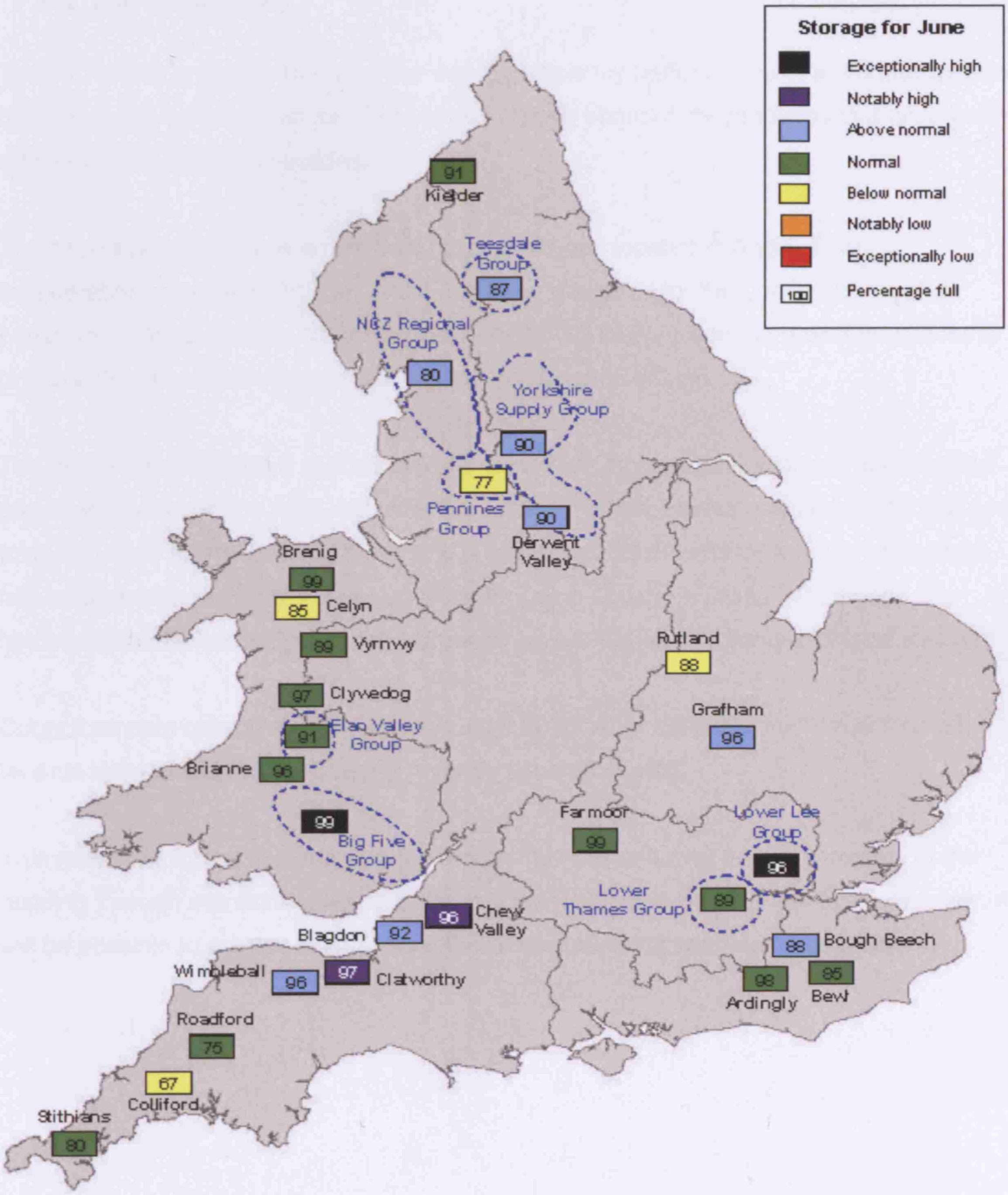


Figure 12- Reservoir storage at the end of June 2006 in England and Wales by Environment Agency Region, as a percentage of total capacity[15]

1.4. Aim of the study

The aim of this project is to review the energy efficiency performance of a low energy new building in the domestic sector. That aims to tackle some of the problems that have been outlined in the previous sections.

The case study building is a new built block of 18 flats located in Angell Town regeneration scheme in Brixton, which has been designed for the London Borough of Lambeth by Anne Thorne Architects Partnership[16] (ATAP); a London based architectural practice that has an environmentally sound approach to design.

The building benefits from various low energy enhancing features, such as: photovoltaic panels integrated in the roof, rainwater harvesting system, environmental friendly and non-toxic materials for the building fabric and finishes. In addition, the orientation of the flats has been designed to maximise passive solar gains and the building layout and landscaped external design influences positively the community integration and safety.

Council tenants occupy the flats since August 2005. After almost a year since the first tenants have moved in, the building is ready to be evaluated.

This report will focus on identifying the factors that are affecting the performance of the building through monitoring, observation and feedback from the occupants. Conversely, it will be possible to assess the influence that such a building has had on its residents.

[1] Intergovernmental Panel on Climate Change (2001) Third Assessment Report, Climate Change 2001: The Scientific Basis. www.ipcc.ch (accessed on June 2006)

[2] Keeling, C.D. and T.P. Whorf (2005) Atmospheric CO_2 records from sites in the SIO air sampling network. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. http://cdiac.ornl.gov (accessed on June 2006)

[3] DTI Energy White Paper (2003), Our energy future- creating a low carbon economy.

[4] Environment Agency. Environmental Indicators. www.environment-agency.co.uk (accessed on June 2006)

[5] DTI Energy consumption in the United Kingdom (2001). Available at: www.dti.gov.uk

[6] UK Building Regulations, available at: www.planningportal.gov.uk

[7] J I Utley and L D Shorrock, Domestic Energy Fact file (2006) Owner occupied, Local authority, Private rented and Registered social landlord homes.

[8] Ecohomes assessment tools, available at: www.bre.co.uk

[9] Energy Saving Trust, Low carbon buildings programme, available at: www.est.org.uk

[10] Home Energy Conservation Association website, available at: www.hecafora.com

[11] Warm Front grant-funded program, details available at: www.defra.gov.uk

[12] Energy Efficient Commitment (EEC), details available at: www.ofgem.gov.uk

[13] CLIVAR/PAGES/IPCC Workshop "A multi-millennia perspective on drought and implications for the future" November 18-21, 2003 Tucson, AZ

[14] Department of the Environment Transport and the Regions, "Sedimentation in Storage Reservoirs" Final Report, February 2001, Halcrow Water

[15] Environment Agency, Water Resources Situation, Reservoir table July 2006 available at www.environment-agenct.gov.uk (accessed on July 2006)

[16] Anne Thorne Architects Partnership, more information at: www.annethornearchitects.co.uk

2. Background information

2.1. Sustainable housing developments in Europe

Sustainable housing in Europe has seen some remarkable examples from countries like Germany, Denmark, Sweden and the Netherlands, to name a few, that have been ahead of the rest of Europe in sustainable issues for decades. These countries have achieved an economical stability and have had success in reducing their dependency on fossil fuels. Germany is the most populous country in Europe and accounts for more than 70% of the total European installed PV capacity, while Germany, Denmark and Spain together contribute 80% of the total European wind power capacity[1].
This healthy growth is mainly due to the incentives and support from the government in developing their renewables industry; the removal of the administrative barriers, higher standards for building codes and the commitment of the population that have been educated since a young age to save energy and use their resources wisely.
There are plenty of energy efficient projects in these countries. Here are a few examples, particularly of housing developments:

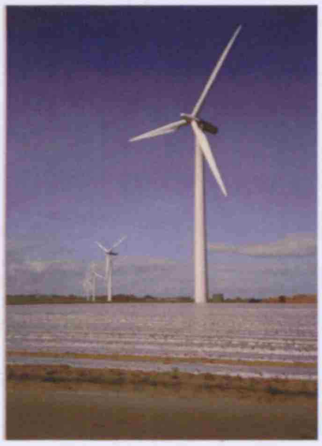
In the Western Harbour area of Malmo in Sweden, Bo01, a new urban district with 1000 dwellings incorporating 100% locally renewable energy has been built[2]. Wind power, photovoltaics and biogas from refuse and sewage form the basis for energy production.

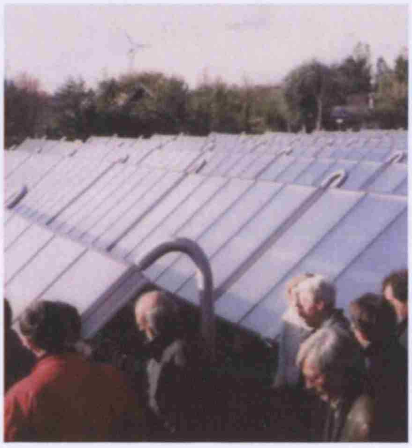

Figures 1 & 2: Sustainable housing developments in Malmo, Sweden[3]

The Western Harbour is able to export energy when production is high and demand is low and import energy when more is needed. A sole offshore wind turbine covers all BO01 electricity needs. The plan is in continuous development for the next fifteen years and should house around 30,000 people by 2020[4]. The European commission and the Swedish government have contributed to this project, which demonstrates the feasibility of building a new urban district with no additional CO2 emissions from energy production.

Denmark has the highest per capita expenditures for R & D (Research and Development) for renewables in the world, with all revenues earned from the industry being invested back into it. Denmark's target by 2030 is to have 30% of their energy being supplied by wind power and increase the contribution of renewables to total energy at a rate of 1% a year. The small island of Samso, Denmark was chosen by the Danish government to become "the renewable energy island" and become totally sustainable by 2008 in a competition held by the Danish Energy Agency.

Onshore and offshore wind turbines with additional supply of solar photovoltaics provide all the electricity needs for its 4,300 inhabitants, and a surplus that is sold to the mainland. Local biomass resources, solar hot water panels, landfill and biogas are also used as a source of energy. For transportation, they grow rapeseed and produce rapeseed oil, which can be put directly into the fuel tank. Community commitment proved to be vital for the success of this project as the locals mobilise to gain support and actively join the scheme.[5]





Figures 3 & 4: Wind power and solar collectors in the island of Samso, Denmark[6]

Germany is the world leader in efforts undertaken to prevent climate change. As the biggest contributor towards the reduction of emissions, today their greenhouse gas emissions are 19 percent less than the volume registered for 1990.
In 1997 three North Rhine- Westphalian (NRW) ministers of Energy, Urban Planning and Research and the NRW State Initiative on Future Energies launched a campaign to build 50 solar energy housing estates, which includes new build and renovation of existing housing estates, these are due for completion in the next few years.

This project aims to demonstrate the possibilities of both passive and active use of solar energy and support the commercial launch of solar building. The housing includes passive solar design such as optimum orientation and high standards for insulation and windows; as well as photovoltaic systems and solar thermal collectors [7]

Figures 5 & 6: Solar energy housing estates in North Rhine- Westphalia, Germany [7]

2.2. UK sustainable housing

New sustainable housing developments that include the use of renewable energy sources have been built in the UK in the last years, but mainly as small-scale local initiatives and at a slower pace than in other European countries.

An example of this is BedZED[8], a mixed development built on a brownfield wasteland site in Sutton, which consists of 82 dwellings, 2,500 m2 of workspace, a health centre, nursery, organic café/ shop and sports clubhouse.
The buildings benefit from super insulation, photovoltaic panels, wind driven ventilation system with heat recovery and thermally massive floor and walls for passive heat gains that reduces the need for electricity and heat from the on site combined heat and power (CHP) power plant. The community has a "Living Machine", which uses reed beds to filter sewage water for use in toilets and gardens and collects rainwater to reduce consumption from the mains.
In addition, the photovoltaic panels provide enough electricity to power electric cars for community use thus avoiding the use of fossil fuel cars.
However, there have been some problems in trying to fulfil the zero carbon ambition, which is not surprising for a demonstration project testing new technologies, as stated in Terry Slavin article[9]. The CHP plant stopped operating for several months, forcing the community to be supplied entire by the National Grid. The 'Living Machine" was also closed due to the lack of an operator. To improve this situation, there are ongoing efforts

to find a replacement biomass CHP system, and Thames Water agreed to take over the operation of the Living Machine.

On the other hand, residents mentioned that the building fabric is so well insulated, and the wind driven ventilation works so well, that they hardly need heating in winter. The conservatories (sunspaces) generate mixed feelings: they are very efficient trap heat in the winter, but overheat during summer, at a time when summers in Britain are getting warmer. Figure 9 shows the photovoltaics cells integrated on the sunspaces' glass roof. The lack of adequate shading on almost horizontal panes of glass allows the sunspaces to overheat. In winter they work well, because the internal façade closes and prevents heat loss to the sunspace.

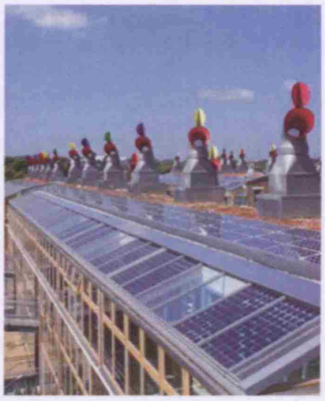


Figure 8 & 9: BedZED development in Hackbridge, Sutton[8]

2.3. `Social benefits of energy efficient housing

Energy efficient housing developments built in the last years usually include a series of features like on-site energy generation from renewables, natural ventilation and high specification of the building fabric to prevent heat loss, while some deal with water recycling and wastewater treatment.

In the most successful cases the planners have also provided carbon neutral means of transport for its residents and a safe community enhancing urban layout with green space and leisure areas.

It is expected that residents would benefit from environmentally friendly homes on a greater scale than from mainstream housing. In a successful development, here are some of the aspects from which the residents could receive a beneficial impact:

Healthy environment

The use of natural and low embodied energy building materials and natural paints, natural linoleum and timber flooring together with the lack of heavy traffic discouraged by the streets layout have a positive influence. Health problems i.e. respiratory problems, including asthma, should benefit from this environment.

Less expenditure

The reduction in energy bills due to the on- site energy generation from renewable systems increases the disposable income of the household, which can be spent on entertainment and other activities enhancing the family's quality of life.

Environmental Safety

A self-sustainable development that does not depend on fossil fuels will continue running unaffected by any fossil fuel crises, high prices, energy shortages, power failures and the chaotic consequences of fossil fuel depletion in general. Residents of such a development can feel less worried about the future, and should feel relieved and fortunate living there.

Personal Safety

A well-designed development creates an internal network of intersecting streets, which are easily accessible and benefit from green areas, street furniture and spaces where people can interact and relax, enhancing the community life. Narrow passages and hidden corners have been avoided, as those encourage crime. Windows overlook all pedestrian transit routes. Living in a place like this would make residents feel safe, thus raising their quality of life.

Environmental satisfaction

Living in a building that facilitates low energy consumption, is likely to make residents more aware of the environmental problems and keen to make an effort to protect it. Contributing actively to reduce their impact on the planet is likely to raise a sense of selflessness and altruistic values in certain individuals (see 2.4), and satisfaction about the environmental goals achieved.

2.4. The impact of human behaviour in energy efficient buildings

Performance in-use of such buildings is very dependent on people's attitudes towards energy conservation.

A study by Nigel Humprey[10] reveals that lifestyle is a very important element of low energy buildings that people are not quite aware of: "Even if I design it (the building) to be zero CO_2. this will only have made a third of the real savings required if they (the residents) are anything like the average UK inhabitant". The remaining two thirds can only come from all the other areas of activity in their life and making these savings will mean making lifestyle changes".

Residents of energy efficient building's would ideally be very environmental aware individuals who appreciate the special features these building have, know roughly how they work and the purpose of their existence, and would aim to achieve the full potential they have. In practice, this is not usually the case. There is a range of different people that currently occupy such buildings: homeowners, tenants, single occupants, large families, people with different levels of education and income, different sets of values and beliefs, and therefore different attitudes towards the environment.

Individual and collective interests struggle with choices that have an impact on household consumption, such as:

- Switching off the lights when leaving a room.
- Having low- energy lighting only.
- Switching off VCR's, televisions and computers instead of leaving them in stand-by.
- Using the washing machine only when is fully loaded.
- Putting a lid on the pot when cooking.
- Using the tumble dryer only in winter.
- Reducing the standard heating temperature, and wear more clothes indoors.
- Reducing the usage of electric powered appliances, and when buying choose energy efficient ones.
- Avoid opening windows unnecessarily when it is cold outside to prevent heat loss.
- Using cold water when washing dishes and doing it in a container instead of under running water.
- Taking a quick shower instead of a bath.

Other choices that are not reflected in the household bills, but are equally important in a broader sense to reduce the environmental impact of the residents are:

- Choosing to walk, cycle and use the public transport instead of owning a car.
- If owning a car, choose one that can run powered with renewable energy.
- If possible, not travelling by air.
- Increasing the percentage of local and organic food and on your diet.
- Avoid buying goods that have too much packaging.
- Recycling everything that can be recycled.

Many of these choices result in money saving, like reducing the use of electricity; or in time saving, like taking a shower. In this case time and money saving becomes usually the main reason people are willing to perform them. Conversely, when the choices are more expensive to perform, or are more time consuming (like locally sourced food or separating and rinsing the recycling contributions), the motivation to perform them is likely to come from an authentic environmental concern and personal values.

Poortinga, Steg and Vlek[11] conducted a study that investigates the relationship between personal values and environmental behaviour; in the field of household energy use to examine which factors lead to higher environmental impacts on households. Expectedly, household energy use appeared to be especially related to household size and income and contextual factors such as individual opportunities and abilities.

However they agreed that personal values serve as guiding principles in life and act as guidelines of behaviour. Environmental behavior is clearly related to basic human values. For this research they identified seven value dimensions and contrast them with the environmental concern of the people interviewed. They found that environmental concern was related to the "achievement value" dimension. People that value their achievements in life, including education and career, tend to have more willingness to protect the environment. Conversely, environmental concern was negatively influenced by the extent one thinks personal prosperity is important, which could be interpreted in terms of a selfish pursuit of personal success and money. Other value dimensions were not so clearly related to environmental behavior.

The study carried out by Steg, Dreijerink and Abrahamse[12] reinforces these ideas. They test the value- belief- norm (VBN) causal chain theory, which proposes that a stable set of general values affect beliefs about human- environment relation, awareness about consequences and responsibility, which in turn influences personal norms and behavior.

In this research they distinguish three main value orientations: egoistic, altruistic and biospheric values, with the following characteristics:

- Egoistic values, which drive people to maximise their individual outcomes are associated with lower environmental concern.
- Altruistic values reflect concern for the welfare of other human beings beyond a person's immediate own interests and are more likely to engage actively in pro - environmental behavior.
- Biospheric (or ecocentric) values reflect concern for non-human species and the biosphere in a broader sense and have a strong moral motivation. These values are more important in stimulating pro-environmental behavior than are altruistic values.

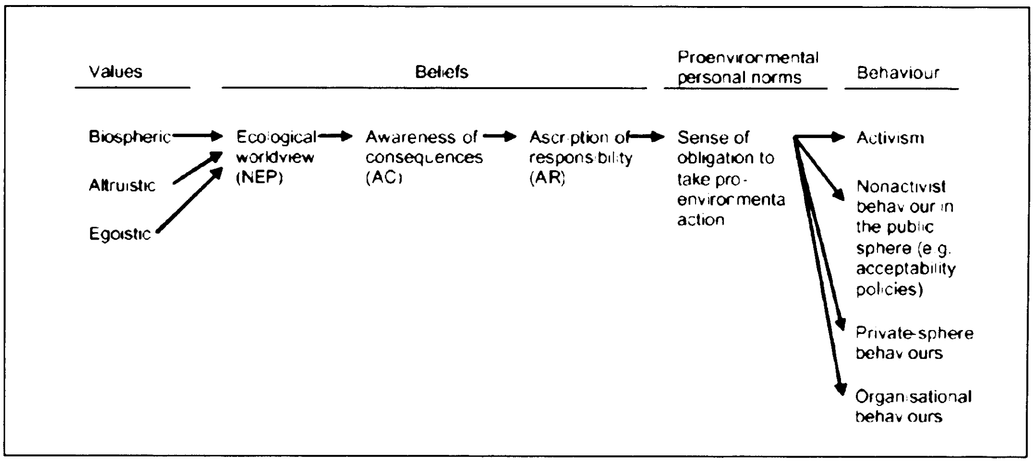


Figure 10: A schematic representation of the VBN theory of environmentalism [12]

Linden, Carlsson-Kanyama and Eriksson[13] carried out a study on efficient and inefficient aspects of residential energy behavior, in which they identified a series of behavior patterns and revealed which ones have an influence on energy use in households. This study is based on a survey of 600 Swedish households where key questions were raised. Some relevant questions have been selected and customised to be included into the tenants questionnaire used for this dissertation, which can be seen in Chapter 6.

[1] S. Slingerland and R. Schilleman, Renewable Energy Sources in the new member states of the EU, December 2004, C E Publications.

[2] Responding to climate change 2006, available at: www.rtcc.org (accessed on June 2006)

[3] Photographs taken from: Building for life, CABE Newsletter 04, July 2005

[4] Oliver Lowenstein, "Eco- Malmo," Building for a Future, Spring 2006, 12-6.

[5] Towards 100% RES supply on Samso, Denmark. Three years of experiences in a planning period over ten years, available at: www.insula.org/islandsonline

[6] Photographs taken from: http://ide.idebanken.no

[7] Landesinitiative Zukunftsenergien NRW, 50 Solar Energy Housing Estates in North Rhine Westphalia, CEBC Meeting Berlin, 2003, available at: www.cebc.co.uk

[8] BedZED development in Hackbridge, Sutton. www.zedfactory.com

[9] Terry Slavin, "Living in a dream", The Guardian, May 17, 2006

[10] Nigel Humprey, "How much is enough?" Building for a Future, Spring 2006

[11] Poortinga, W., Steg, L., & Vlek, C. (2004) Values, environmental concern and environmental behavior: A study into household energy use. Environment and behavior. Journal of Environmental Psychology, 36(1), 70 –93.

[12] Steg, L., Dreijerink, L., & Abrahamse, W. (2005) Factor influencing the acceptability of energy policies: A test of VBN (value, belief, norm) theory. Journal of Environmental Psychology, 25, 415-425.

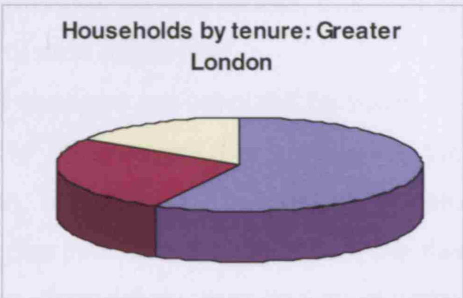
[13] Linden, A. L., Carlsson-Kanyama A. & Eriksson, B. (2006) Efficient and inefficient aspects of residential energy behavior: What are the policy instruments for change? Journal of Energy Policy, Elsevier Ltd. 1918-1927

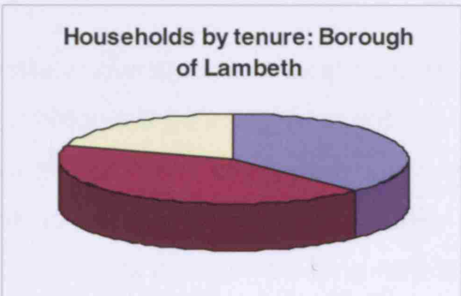
3. Site Overview- Angell Town

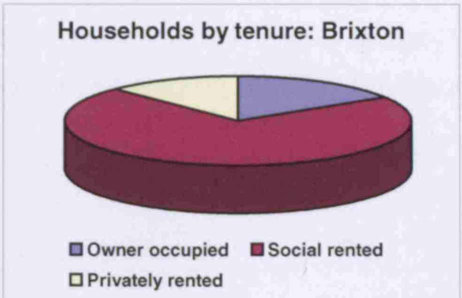
3.1. Social Housing in Brixton

Brixton is well known as a multi ethnic and vibrant community in the South of London with a heterogeneous mix of population, who live predominantly in local authority housing. The figures 17, 18 and 19[1] show the contrast between the housing distribution by tenure in Greater London, in the borough of Lambeth, and in the Brixton area where Angell Town is located. In greater London most houses are owner-occupied, in Lambeth the number of social rented houses is in balance with the owner occupied and privately rented ones, while in the Brixton area 71% of the housing stock is owned by the council and housing associations.

The area considered as Brixton in this chapter corresponds to Lambeth 011 area code on the National Statistics system.[1] The limits of this area are show in Figure 20.







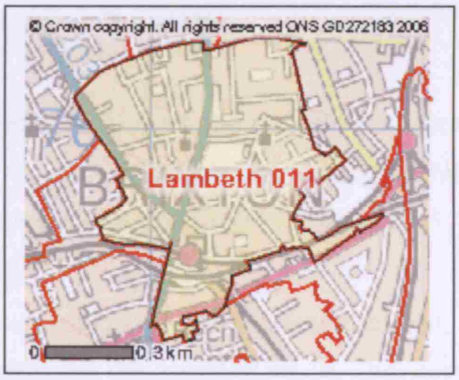


Figure 4: Map of Lambeth 011 [1]

Figures 1, 2 & 3: Households by tenure in Greater London, Lambeth and Brixton [1]

After the Second World War, the housing shortage forced the government to build large housing developments with high-rise buildings in the city, and Brixton had its share of them. Large estates like Loughborough, Brighton Terrace, Stockwell Park and Angell Town estates to mention a few were built without considering energy conservation issues and community building layout. They became overcrowded and declined into focal points of anti-social behavior and social exclusion.

In the 1980s as a result of poverty, unemployment and deep social tension the area witnessed violent episodes of riots between young people and the police. The estates were stigmatised as 'no-go' areas, their people endured high crime rates and the housing stock was in serious disrepair.

Although Lambeth was ranked the 17th most deprived out of 354 London Boroughs in 2004[2], the situation has improved since then, and now Brixton's face is changing due to new upmarket developments, businesses and entertainment venues that are attracting an influx of new residents.

These changes are criticized by some of the well-established residents, such as Paul Bakalite[3], who claims that 'gentrifying' the area is increasing the social differences within Brixton. The variety of cultures and mixed population that created Brixton unique 'hip and edgy' qualities do not benefit from the newcomers wealth and associated businesses and venues. Conversely, they find them exclusive and expensive, he states.

Fortunately, investments in existing social housing stock are also on the agenda and more than £2 billion will be invested in improving London's housing conditions according to the 'London Housing strategy'[4], from which up to £420 million will be provided to London councils to improve the condition of their existing stock.

The programme includes building new housing for overcrowded and homeless families, regenerating deprived estates and improving the condition of the housing stock, especially the social rented homes. This is already benefiting Brixton, through many initiatives carried out by Lambeth Council, like the regeneration of Angell Town Estate.

3.2. Angell Town Estate

Angell Town estate is located just north from Brixton town centre, and was completed in 1978 to fill the critical housing shortage. The original design scheme consisted of four storey blocks, with access corridors. Each block was linked to the next by high-level concrete bridges with car parking and bin stores at ground level.

The concrete bridges were unsafe as they provided an easy getaway for thieves, and the car park was not used, partly because very few residents owned a car and partly due to poor lighting and the presence of vandals. This generated a vast area at ground level, with many hidden corners used for criminal activities and drug dealing.
The staircases were enclosed within the building, which make them an easy base for muggers.

The scheme design emphasized the anonymity of every home, and did not provide adequate community spaces, which discouraged community integration. This sense of hopelessness was aggravated by the stigma surrounding the estate, and those living in it suffered from high rates of unemployment and social exclusion.

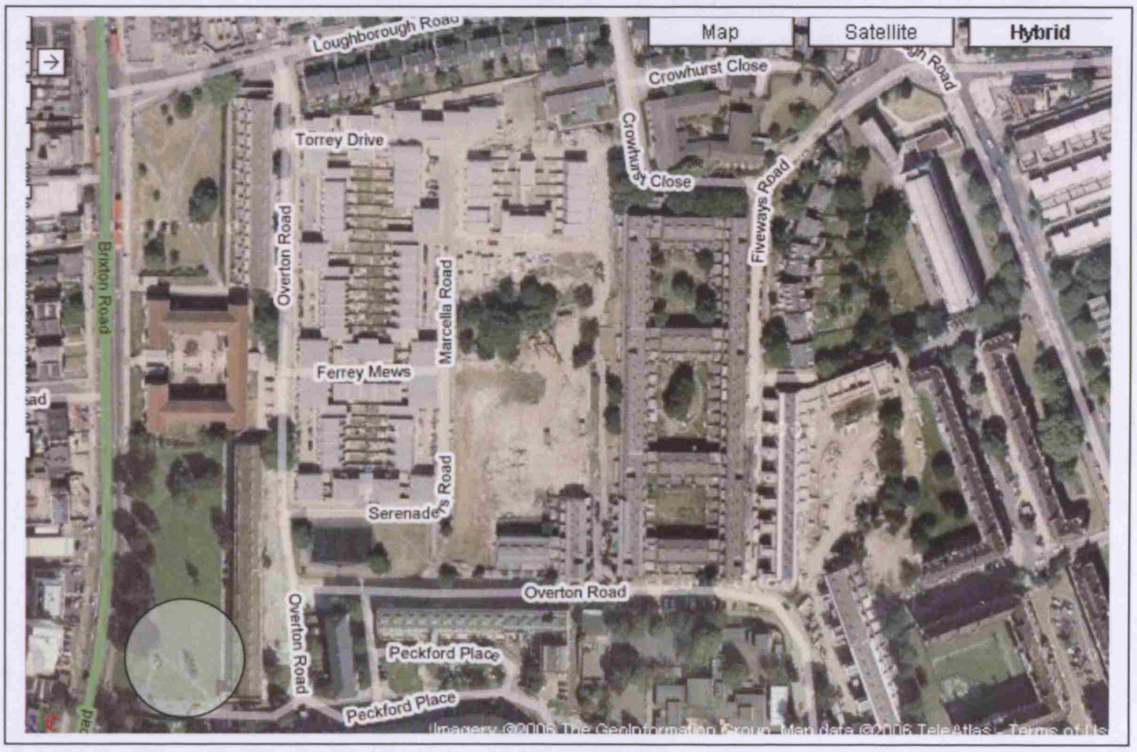


Figure 5: Aerial view of Angell Town[5] circa 2001, before Boatemah Walk development was built (site encircled)

Energy saving was not considered in the original design. The buildings lacked insulation and had badly fitted single glazed windows which led to cold bridging, draughts and heat loss, aggravating fuel poverty.

Figure 6: Angell Town before regeneration provided many hidden corners[6]

Figure 7: Smashed windows covered with cardboard or plastic were a usual view

3.3. Urban Regeneration of Angell Town

Angell Town is currently undergoing a multi-million pound regeneration programme funded that has seen a major change in the environment, safety and quality of life of the residents. In the 1990s the first steps were taken with the demolition of the high-level bridges and ground level garages were converted into retail premises.

Figure 8: Ground level garages converted into retail premises

Five architectural practices were appointed to design high quality homes taking into account energy efficiency, security and community integration. As stated on the London Borough of Lambeth webpage[7], existing flats have been refurbished to high specifications including:

- Insulation in roofs and cavity walls
- Insulated timber framed external cladding to solid walls
- External insulated render to avoid cold bridging
- Low E double glazed timber frame windows
- Condensing boilers with thermostatic controls
- Low energy light fittings
- Passive stack ventilation
- Certified timber from sustainable sources
- Low embodied energy material wherever possible

Flats at ground level have now front doors to the street, which makes streets naturally overlooked and safer. The landscaped streets and gardens create areas for people to enjoy outdoors and meet their neighbours.

The construction process required the temporary relocation of existing tenants, but all of them had the right to return into the modernised flats.

Figure 9: New and refurbished developments create a street layout with natural surveillance

Figure 10: Named crossroads to bring individuality on every corner

Figure 11: Boatemah Walk new building

In addition to the buildings improvements, there has been a lot of work done to make the community stronger and provide more local jobs. Involving the residents at the design stage and construction process has led to a sense of pride and ownership in the place. In 2002, part of this development was received the RIBA housing award 2002 and in 2003, Angell Town estate was recognised by the Deputy Prime Ministers' Award for Sustainable communities for its sense of place, design, and for its safe and healthy environment.

Figure 12: Community sport facilities

[1] National Statistics, Neighbourhood statistics, 2001 Census: Tenure Households, Area: Lambeth 011 available at: www.neighbourhood.statistics.gov.uk

[2] Office of the Deputy Prime Minister, The English Indices of Deprivation 2004, ODPM Publications, April 2004. Pg 163

[3] Paul Bakalite, 'Brixton Blues' Essay. New Internationalist Magazine, December 2005

[4] London Housing Board, Homes and Communities in London: London Housing Strategy 2003, available at www.gos.gov.uk

[5] Satellite images taken from www.maps.google.co.uk

[6] Photograph taken from Building for a Future magazine, Spring 2002, pg.22

[7] London Borough of Lambeth, Environmental issues, Angell Town, available at www.lambeth.gov.uk

4. Project Overview- Boatemah Walk

4.1. Boatemah Walk in context

Boatemah Walk is located on the south of Angell Town, facing towards Brixton Road on the site of half of the previous Warwick House building. Warwick House building was half refurbished, half demolished to allow the space for a new building. The volume of the new building is curved and detached from Warwick house building, opening sightlines and clear pedestrian routes from Brixton Road into the new Angell Town and breaking the previous barrier that once separated the main road from the estate. Anne Thorne Architects Partnership were appointed to design a residential building with high standards of energy efficiency and incorporating on-site renewable energy production and in addition, to design the layout needed to create communal spaces to enhance the community interaction

Boatemah Walk sustainability agenda reaches beyond the current regulations for energy efficiency. Moreover, the residents were involved in many stages of the design process, such as the general decision- making and detailed design.

Figure 1: Site overview[1]

The building layout draws a gentle curve that creates two main facades: a longer one facing north-west towards Max Roach Park and Brixton Road; and a shorter one facing south east overlooking the landscaped community gardens. The south-east façade has larger windows than the north-west, and has also balconies, giving a small outdoor space to every flat.

The new building houses 18 flats which replace the ones that were demolished and are distributed in the following way: 3 three- bedroom flats and 1 two bedroom flat on the ground floor; and 2 two- bedroom flats and 12 one- bedroom flats in the upper levels. All ground floor flats have an enclosed outdoor area in each side of the façade, and are designed to be wheelchair accessible. The shared gardens around the building are planted with native species and ground floor flats benefit from patios with beech hedges and railings. Lime trees form a raised hedge to give the residents some privacy on the north west façade[2].

Figure 2: Lime trees in March (left) and July (right)

Figure 3: Boatemah Walk's north west façade as seen from Brixton Road [3]

Figure 4: South- east façade with balconies facing the community gardens

Figure 5: Recycling facilities

This development has a major importance within Angell Town regeneration scheme, as a showcase project that combines low energy design, active solar energy production and a rainwater harvesting system into a social housing development.

4.2. Environmental Strategies

Boatemah Walk building has been designed with many sustainable features to achieve the following objectives:

- **To minimise the embodied energy of the building itself**

The building materials have been chosen aiming to minimise the embodied energy, such as recycled materials, Forest Stewardship Council (FSC) accredited timber for the structure, external cladding and internal finishes; recycled newspaper for the insulation, and organic paints which have the added value of an improved internal air quality.

- **To reduce the operational energy use,**

The building fabric insulation achieves a better U-value than required by current building regulations thus conserving the heat and reducing the energy needed for space heating. The light fittings are low energy type.
Passive stack ventilation 'Passivent' was installed for the kitchens and bathrooms instead of mechanical fans to reduce running and maintenance costs.
The building orientation and the layout of the flats are organised to maximise solar gains in winter and reduce the solar penetration in summer on the rooms that are most used. The lower winter sun penetrates deep into the building, while in summer the building overhangs keep the indoor space in shadow, preventing overheating.

All flats have views out of both facades. The living spaces (living rooms and bedrooms) are predominantly south oriented, while the kitchens and bathrooms are north oriented. The figure below show the solar penetration angles in winter and summer.

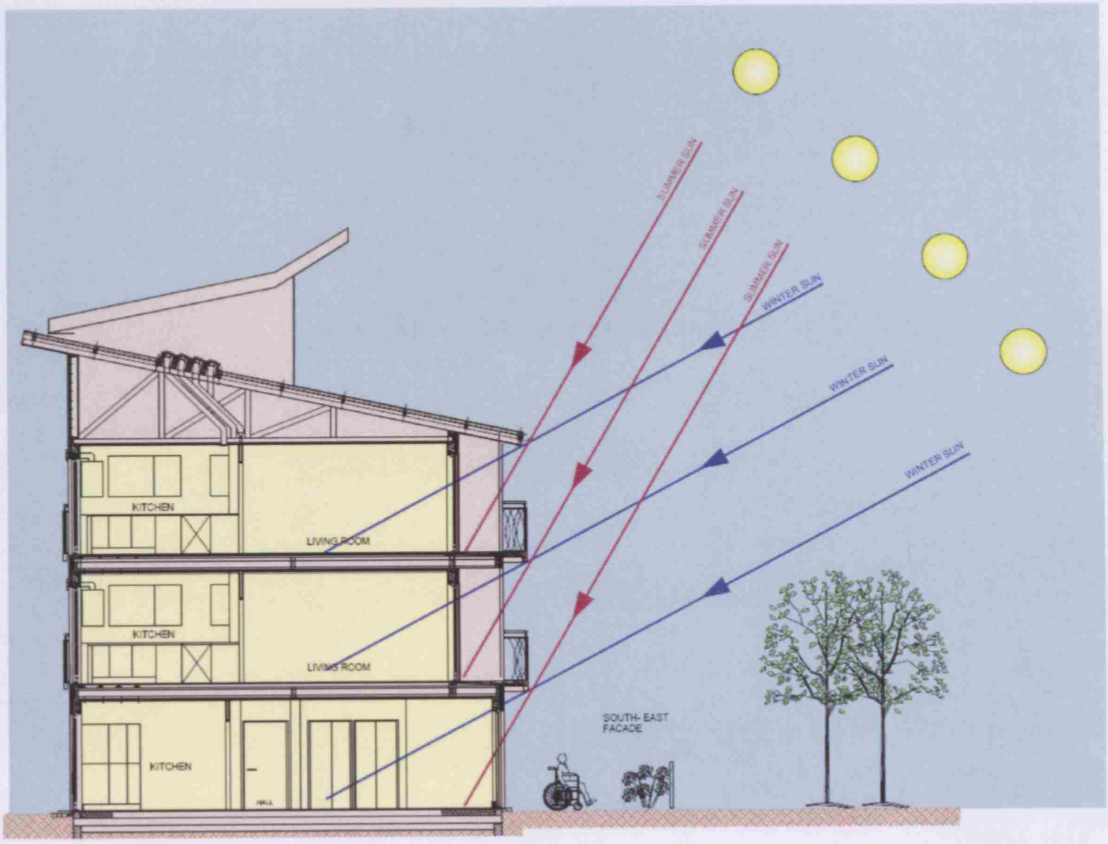


Figure 6: Solar penetration angles in winter and summer[4]

- **To produce clean energy**

The photovoltaic laminate integrated to the roof generates clean electricity even in overcast conditions. The electricity produced is directly distributed between the ground floor flats, reducing losses due to transmission distance. The surplus is sold to the National Grid by Lambeth; hence there is no need for batteries to store energy on site. Additionally, tenants are reducing their dependence from the National Grid. More details will be discussed in section 4.4

- **To reduce the water consumption**

A rainwater harvesting system collects the rainwater from the roof area, stores it in a tank under the garden from where it is pumped to a roof tank. This water is then used for toilet flushing and benefits all 18 flats. Additionally the flats have been equipped with water saving fittings: low water use taps and low and dual flush WC's of 4 and 2.5 litres flush.

More detail to be discussed in section 4.5

The figure below shows a summary of the main environmental strategies in the building.

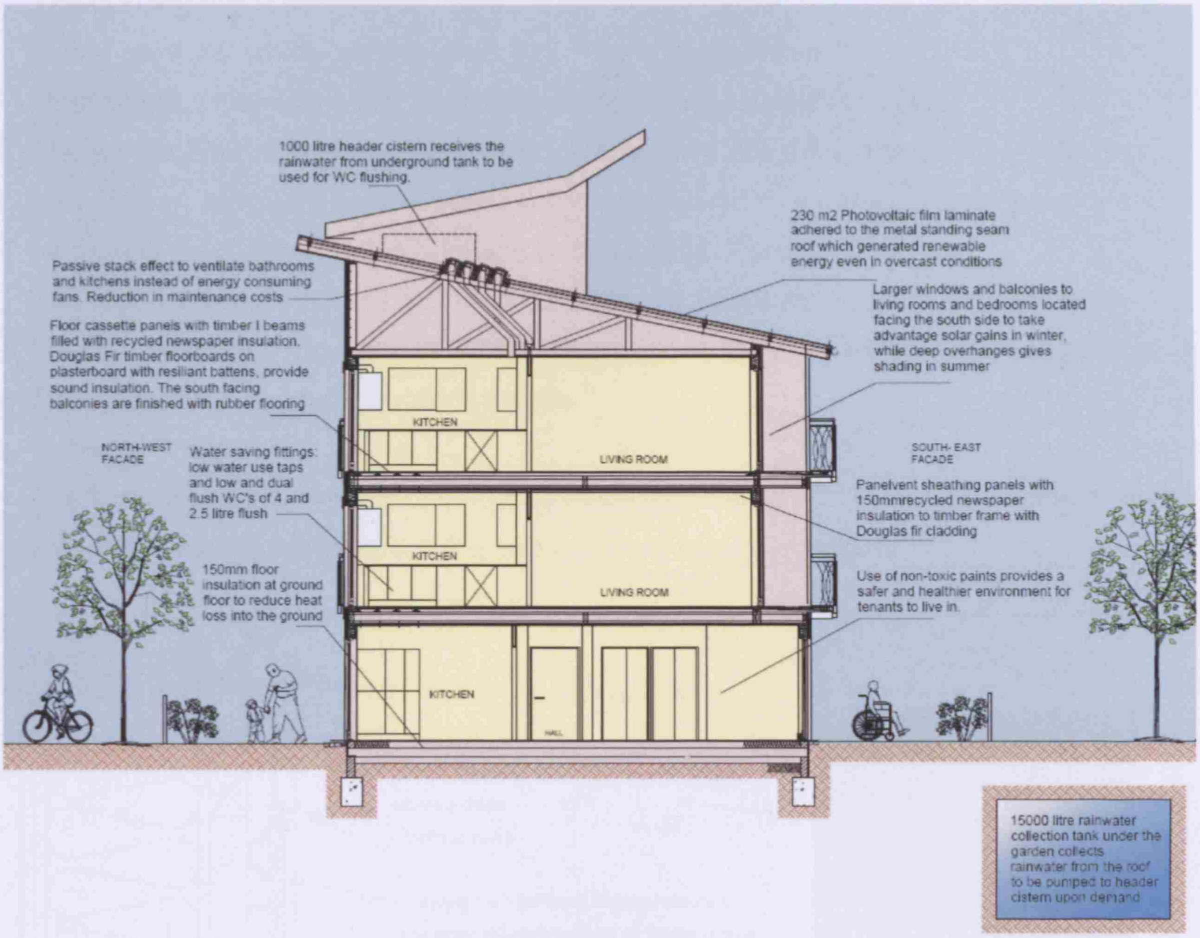


Figure 7: Main environmental strategies [4]

4.3. Materials and finishes

Structure

The building has a concrete foundations and timber framed structure, with 150mm deep timber sections, which has achieved 70% Forest Stewardship Council (FSC) certification. This means that the timber comes from sustainable forests.

The ground floor slab is made of a pre-cast suspended beam and block floor, insulated with 150mm Jabelite. The void below is cross ventilated by means of steel pipework and ventilation cowls taken to the front and back gardens of ground floor flats.

The roof is a ventilated cold roof made of Kalzip AluPlusSolar System[5] wide panel on timber bearers and trusses with 300mm Warmcel insulation and Eternit soffit and fascia. See Appendix B for main junctions details.

External Walls

The external walls are made of timber cassette frame filled with Warmcel insulation, lined externally with panelvent sheathing and a layer of external cladding.

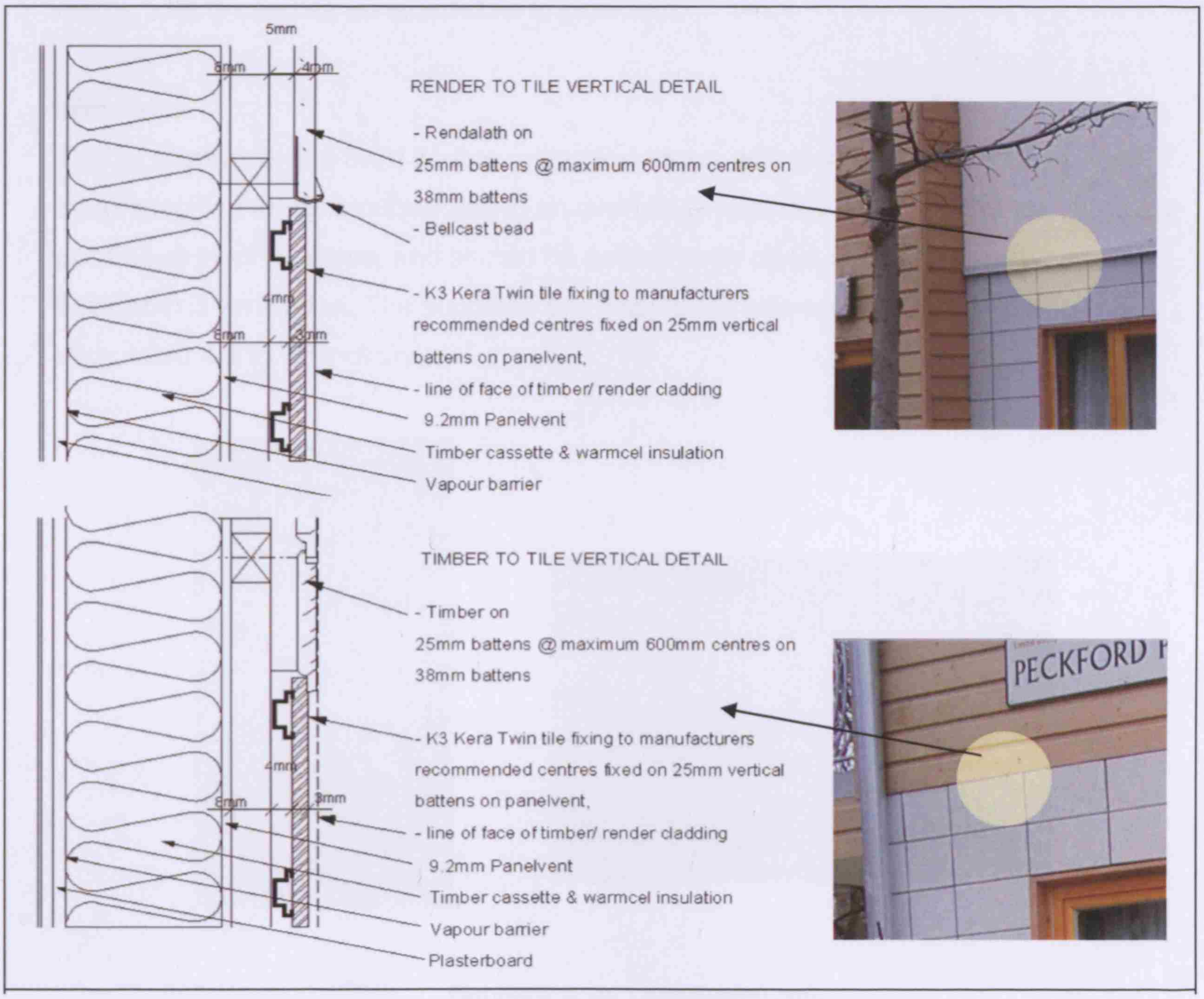


Figure 8: External walls cladding types

Warmcel is manufactured from recycled newspaper and has extremely low embodied energy. It does not contain any added formaldehyde and is free from CFCs, volatile organic compounds (VOCs) or other toxic substances. Panelvent is manufactured entirely from wood waste and does not use any glue in the manufacturing process, relying on natural lignin in the timber as the material binder. [6]

Boatemah Walk building has 3 types of external cladding: ceramic tiles, Douglas Fir timber and render. The ground level has mainly tile cladding to give a tougher finish, while the upper levels have either timber or render cladding.

Figure 8 shows the vertical sections through the external walls, with the correspondent photo of the cladding finish.

Internal Walls

The party walls are made of timber studwork with cellulose insulation, oriented strand board (OSB) sheathing and plasterboard, the internal partitions from timber studwork and plasterboard. OSB sheathing is made of wood chips from fast growing trees and resins, and is used as an alternative to plywood.

Windows

Timber framed, argon filled double- glazed windows with low emissivity coating have been specified for all windows giving an overall U-value of 1.5 W/m²K. Trickle vents are positioned in all windows, and should be permanently open, to allow for minimum background ventilation. The suppliers are Rationel Windows, one of the leading manufacturers in Scandinavia.

Figures 9 & 10: Trickle ventilation

4.4. Building Integrated Photovoltaics

The initiative of Lambeth Council to provide on site renewable energy generation and the grants available at the time for that purpose made possible the installation of a photovoltaic array on Boatemah Walk's roof.

The building's roof slopes 12 degrees maximising the south facing surface, hence the solar radiation. The building integrated photovoltaic system was designed by Solar Century and consists of a special Corus Kalzip aluminium standing seam roof where a 229m² Uni-Solar thin film amorphous silicon photovoltaic laminate (PVL) has been applied.

Figure 11: Photovoltaic array on Boatemah Walk's roof

According to Katharine Scott's[7] study, the system's efficiency was estimated to be 5.8% (average for a year), and together with the annual average solar irradiation data, she calculated that the photovoltaic array would produce a total output of 13.327kWh a year, against the predicted power output made initially of 14.336 kWh. This output was enough to cover the demand of a third of the flats, therefore it was agreed to connect the system's invertors only to the four flats on the ground floor. The ground floor flats were chosen because they are designed for wheelchair users who are more likely to be at home during the day and take maximum advantage of the electricity as it is generated.

There is a reading board located in one of the stairwells, visible from the outside, which records the instantaneous power output of the photovoltaic array, the total amount of kWh generated since installation and the total amount of CO_2 saved. This real time display awakens the curiosity of passers-by and reminds the tenants that electricity is being produced on site.

Figure 12: Solar power reading board showing 1.49 kW being generated on an overcast day

The invertors installed convert the electricity and supplies the flats upon demand. The tenants have been informed of the benefits of using their electric powered appliances during the day, when it is likely to be free. However, when the demand exceeds the production, electricity has to be imported from the grid and tenants are billed for it. Conversely, when supply exceeds demand, the excess should be exported to the national grid and paid to Lambeth, eliminating the need for storage.
However, although specified, export meters have not been yet installed (July 2006).

4.5. Rainwater Recycling System

The average household uses 50 litres per person a day for toilet flushing, representing about 35% off all domestic water use, according to the Environment Agency[8]. As there is no need for having purified drinking water to flush toilets, rainwater is ideal for these purposes and no further treatment is required.

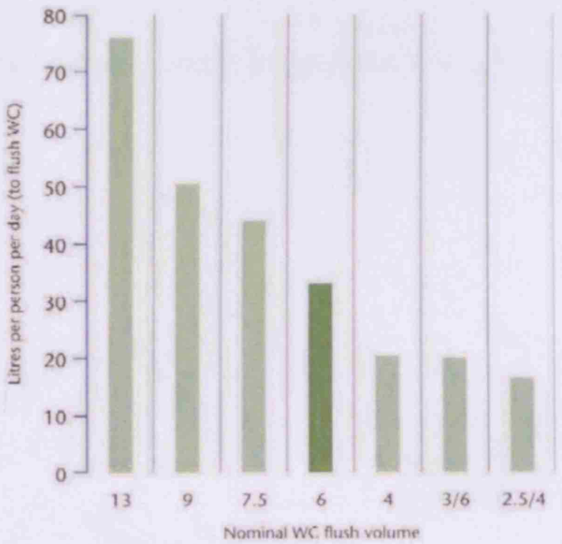


Figure 13: Litres per person per day for toilet flushing volumes (Environment Agency)

A rainwater harvesting system has been installed in Boatemah Walk, aiming to reduce the amount of water consumed from the mains. The rainwater is used only for toilet flushing; hence there is no need to purify it in any way. Additionally, the building benefits from low and dual flush WC's (2.5 and 4 litre) and flow regulators at 4 litres per minute for basins and 10 litres per minute for showers.

How the system works

The rainwater is collected from the roof through the gutter to be filtered and stored into a 15000 litre underground Glass reinforced Polyester (GRP) tank buried under the community gardens. The filter flushes leaves and excess rainwater directly into the main drain pipe. About 85% of rainwater is usually captured, while the remaining 15% flushes with excess rainwater, leaves and other debris. Rainwater then enters the underground tank through a smoothing inlet, designed to avoid stirring the fine sediment at the base of the tank. The tank has been sized to optimise the use of available rainfall. A hydrostatic level sensor inside the tank measures the amount of rainwater and a high-pressure pump is activated when the header cistern needs to be filled. A float switch attached to the pump avoids dry running.

Water is pumped to the header cistern to the full level, and when it is not available a mains back up keeps the water level to a minimum to ensure there is always enough water to flush the toilets. From the header cistern, water is distributed to the 21 WC's in the building.[9]

It was estimated that 220m³ of water a year would be saved from the WC specifications and a further 176 m³ from the rainwater harvesting. Meters were specified to measure the amount of rainwater entering the header cistern. However, these have not yet been installed.

The figure below illustrates the process in a simplified manner.

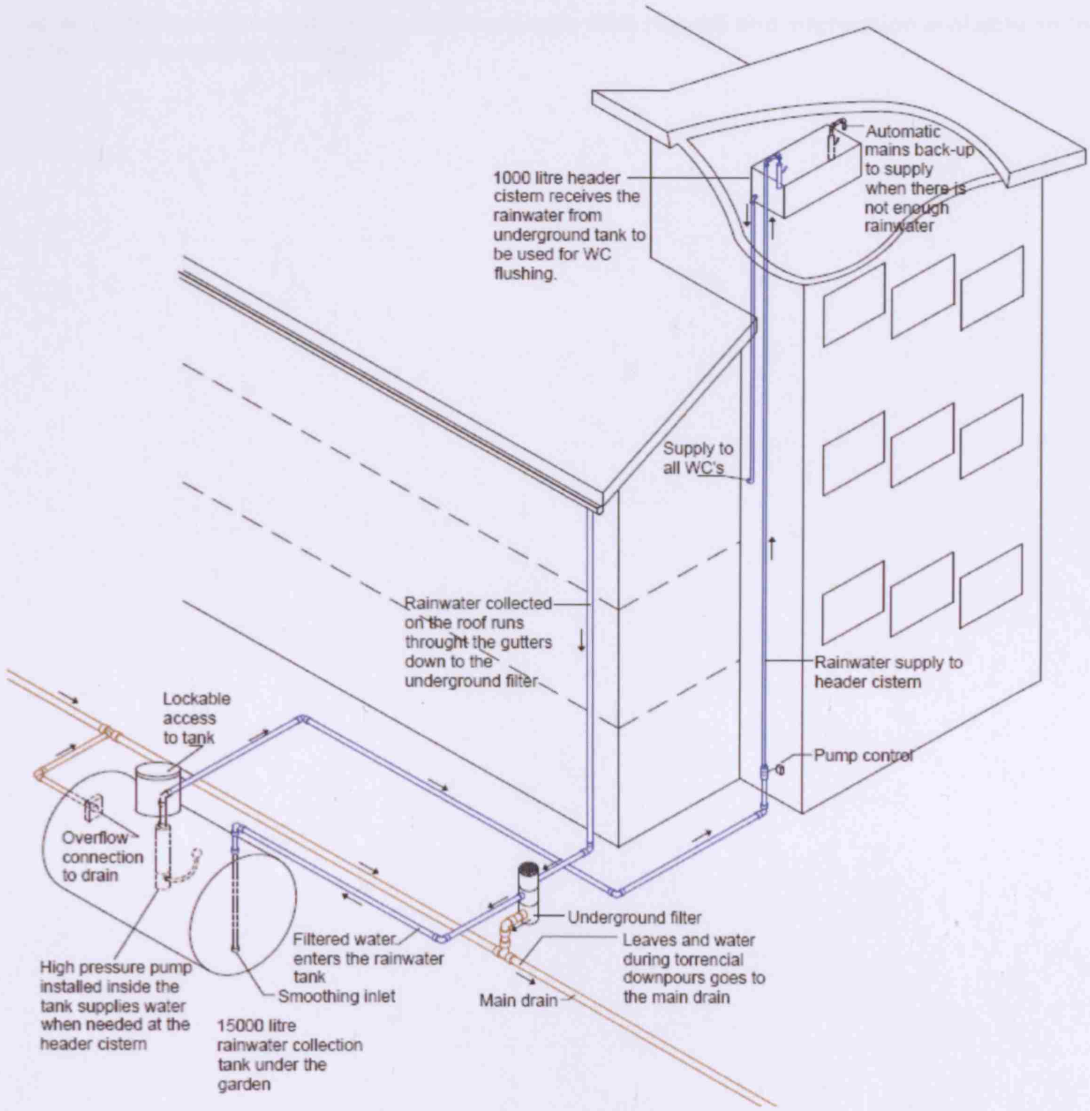


Figure 14: Rainwater recycling system installed in Boatemah Walk[10]

[1] Overview site drawing kindly provided by Anne Thorne Architects Partnership

[2] Fran Bradshaw "Eco-eden in Angell Town" Building for a Future, Winter 2005/06, pg 10-14

[3] Photograph taken from Building for a Future magazine, Spring 2002, pg.22

[4] Drawn by the author with information taken from ATAP drawings.

[5] More details on Kalzip AluPlus Solar roof available at: www.aluplussolar.com

[6] More details on Warmcel insulation and Panelvent sheathing available at: http://www.excelfibre.com

[7] Katharine Scott "Building integrated solar energy at the scale of a small residential block in the UK" MSc Dissertation, University of London, 2005

[8] Environment Agency, Water Sources, Rainwater reuse, available at: www.environment-agency.gov.uk

[9] Rainwater recycling system was installed by Construction Resources, www.constructionresources.com

[10] Drawn by the author following conversations with Cath Hassell and information available on the Construction Resources webpage.

5. Building Monitoring

5.1. Gas consumption and indoor conditions

In this section, data from meter readings and indoor temperature and humidity monitoring will be presented to allow for comparisons when applicable. The meter readings have been made regularly by visiting the tenant's homes and checking their individual meters. The temperature and relative humidity have been collected using a data logger placed inside their flats.

The flats are designed with high specifications to conserve energy, therefore it is expected that less gas will be needed for heating per square meter than in an average UK household. Of course, this does not depend entirely on the qualities of the building fabric, but also to a greater scale on the occupant's behavior. How warm do they like to have their house? Do they like to recreate summer temperatures indoor during the coldest months?

The main limitation encountered when gathering data, was the availability and willingness of the tenants. They all received letters and only the ones who answered were visited. These tenants had data loggers installed into their flats and their meters were checked to collect data. The labels for flats assigned for the purpose of this analysis are shown in Appendix A. They are different from the ones in real life, and will be consistent throughout this report.

Figure 1- gas meter on a ground floor

The flats in Boatemah Walk require gas for space heating, hot water and cooking. The gas central heating consists of a condensing boiler and radiators in every room. The energy efficient condensing boiler installed in the kitchen controls the heating and hot water modes, the temperature and has a timer that switches it on and off automatically. Every radiator has also temperature controls.

Figures 2 and 3- condensing boiler and radiator

5.1.1. Monitored gas consumption- Seven flats

Between February and July 2006 the consumption of gas in seven flats (including all ground floor ones) was monitored through meter readings. The flats were chosen due to their size differences and the possibility of access since February 2006.

Flat A, B and C are the largest homes with 115m², flats D and T have 77m² and flats R and N have 52.7m². The results are shown in figure 4.

Expectedly the largest flats have the highest consumption, as more space needs to be heated. Despite being much smaller than flats A, B and C, flat T gas consumption follows very close behind. One of the reasons for this might be that the occupants, 2 adults and 2 children, like to have the house much warmer.

- The smaller flats, R and N have consumed considerably less, not only due to their size difference, but also to the patterns of occupation. Single working people, who spend less time at home, occupy these flats.

- As expected, the seasonal temperature variation is reflected in the gas consumption, and the proportion of gas consumed for space heating is evident as more gas was consumed in the coldest months of January, February and March and less towards the spring. The consumption peaked in March as temperatures dropped to almost 0°C, the coldest month this year so far. Figure 5 shows the temperature recorded for the same period of time.

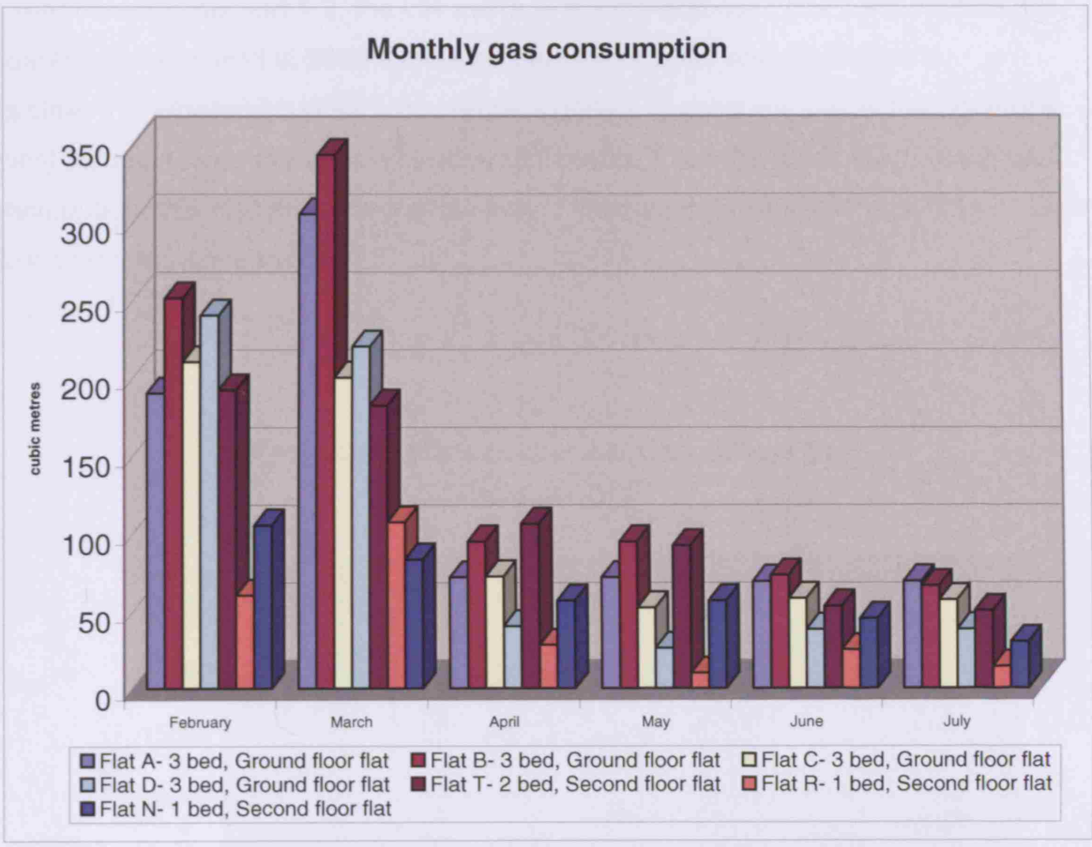


Figure 4- Monthly gas consumption from February to June

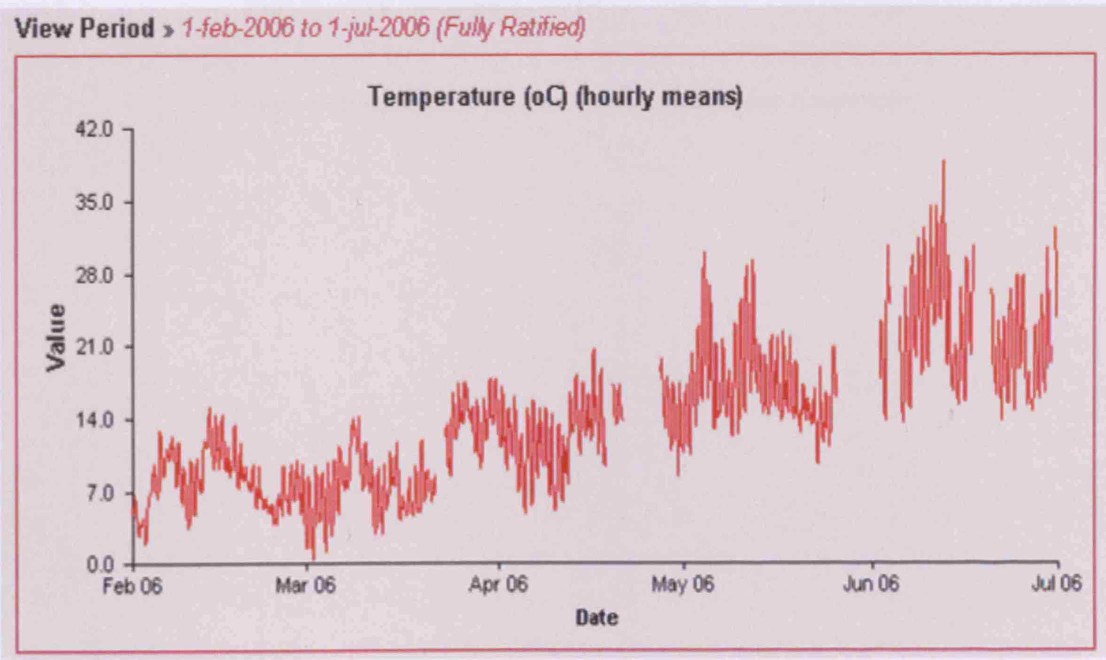


Figure 5- Temperature records from February to July'

The gas readings collected during six months include summer and winter months thus are representative for half year consumption. The projected annual consumption has been calculated using this data as shown in figure 6.

As mentioned in section 1.2, the UK average annual domestic gas consumption per households measured in 2003 fluctuates between 18,000 and 22,000 kWh.

It is clear that Boatemah Walk's households generally consume below the country's lowest values. Given that space heating represents a considerable share of the gas consumption, this confirms the contribution of Boatemah Walk's energy efficient building fabric to energy conservation.

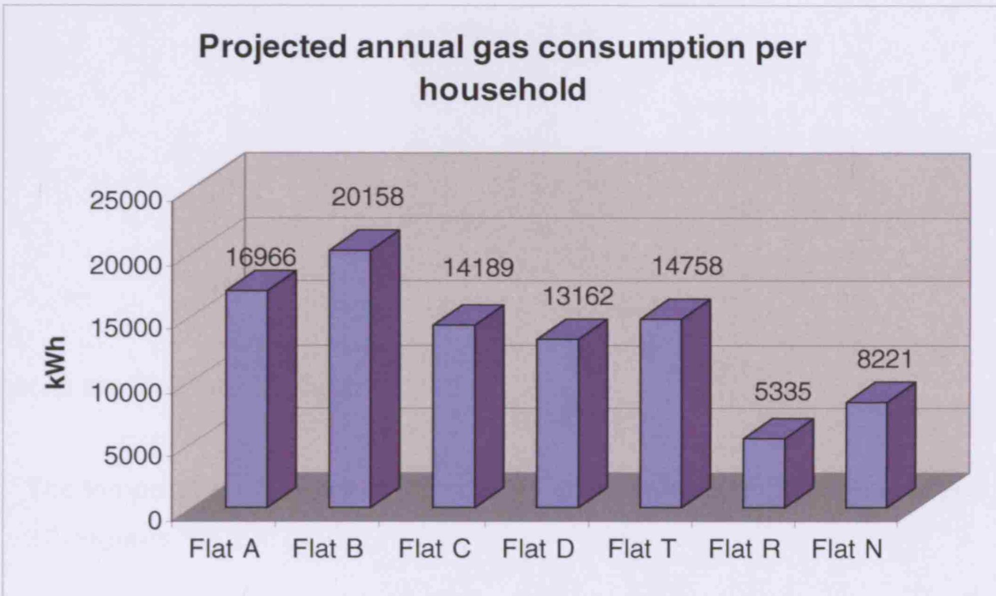


Figure 6- Projected annual gas consumption per household

5.1.2. Winter recorded temperature- one flat sample

Data for temperature and relative humidity was collected in 3 different rooms of Flat T using a data logger from the 25th of November to the 20th of December. Flat T is a 2 bedroom, second floor end flat, with 3 exposed surfaces.

The family consists of two adults and two children, whose patterns of occupation repeat every day. The data loggers (see figure 7) were placed in the living room, bedroom 1 and kitchen (see appendix A for flat location and layout), away from windows and radiators that could distort the temperature recorded.

Figure 7- HOBO Data logger[2]

The results are illustrated in figure 8:

- The temperature variation in all three rooms monitored fluctuates between 20 and 27 degrees °C.

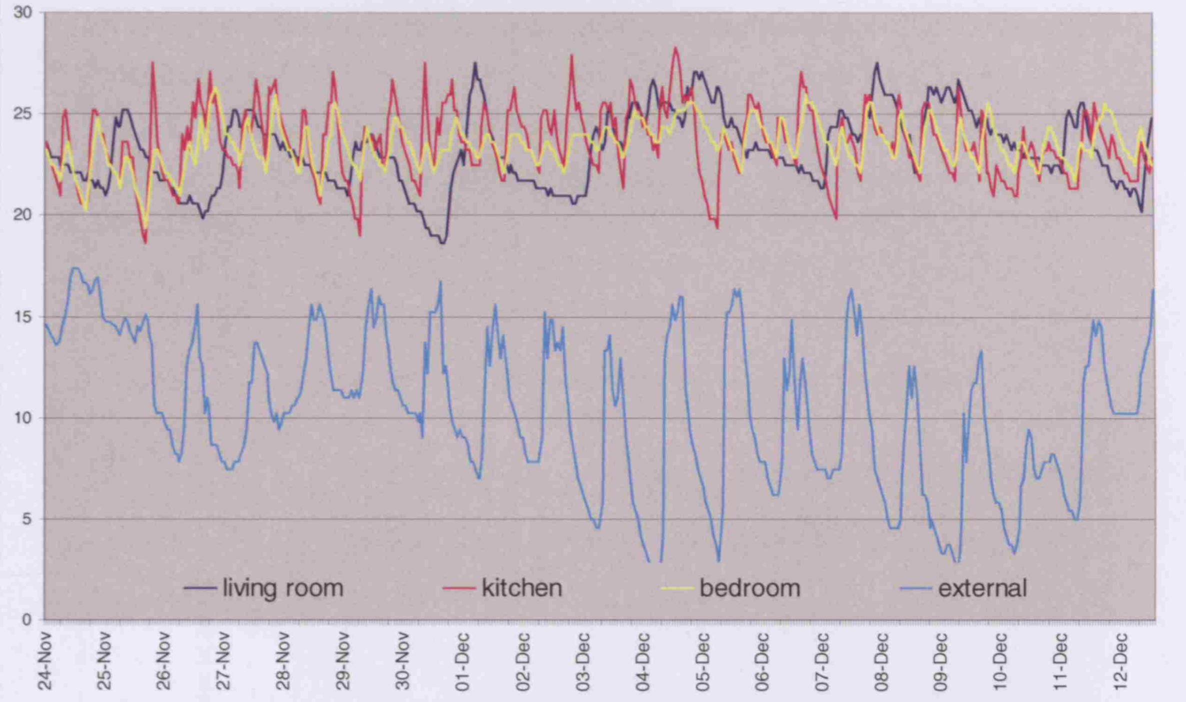
- The occupants mentioned that the heating is usually on only between 5 and 9 in the evening, and lowered at night, which is visible through the recorded data.

- The most stable temperature with a minimum of daily variation is found in the bedroom, to the north side, where the door is usually kept closed.

- The kitchen and living room are linked by a glass door, which is usually kept opened. However, the kitchen temperature peaks high and low every day, presumably coinciding with cooking times and rapid ventilation (window opening).

- The living room has a random temperature variation, not a daily pattern, but reaches peaks every two days approximately. The tenants also pointed out a gap in the living room doors that leads to the balcony, which prevents them from closing properly. This could result in continuous air leakage compromising the flat's air tightness throughout winter.

Figure 8- Recorded Temperature Flat T
24 November - 12 December 2005

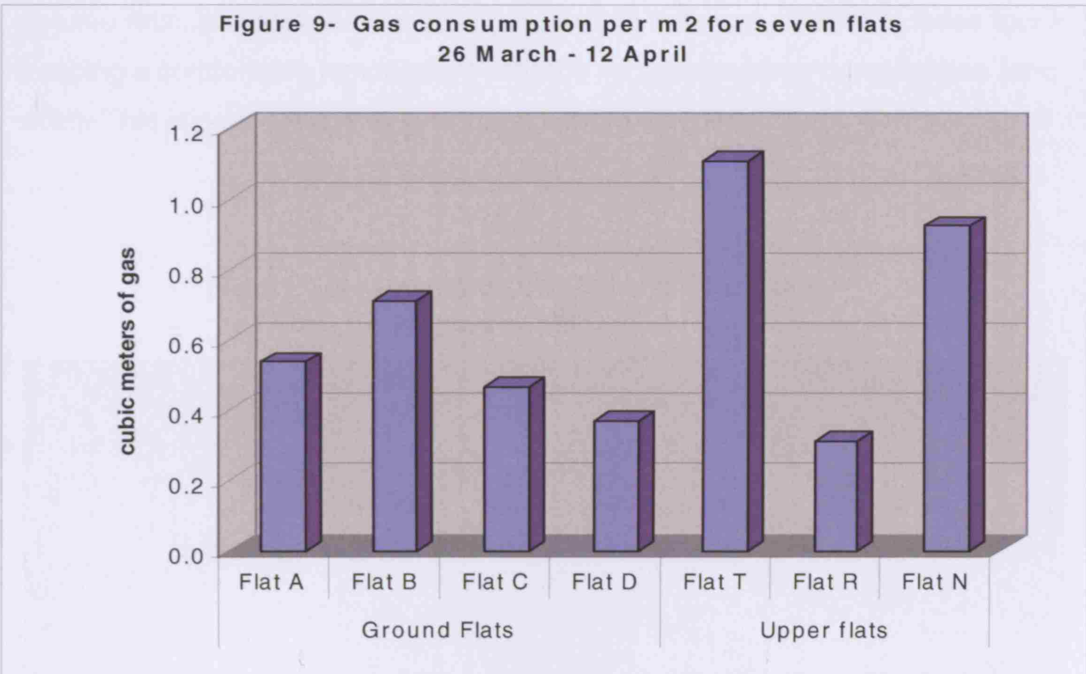


5.1.3. Spring recorded temperatures and gas consumption- Seven flats

Between the 26th of March and the 13th of April 2006 seven flats (four in the ground floor and three in the second floor level) were monitored using the data loggers. In all cases the data loggers were placed in the living rooms, one in each flat. During the same period of time, the gas meters were read. Due to the fact that space heating takes a considerable share of the total gas consumed in a household, this exercise will allow verifying the connection between both.

Flats A, B and C are the largest with 115m² each, flats D and T have 77m² each, while flats R and N are the smallest with 52.7m² each (see appendix A for flat location and layout). Flats A, B and C are the largest with 115m² each, flats D and T have 77m² each, while flats R and N are the smallest with 52.7m² each (see appendix A for flat location and layout). In order to compare their consumption with a fixed variable, the gas consumption was divided between the area of each flat and the results per square meter are shown in Figure 9.

- On the ground floor, flats A and D (end flats) consume less gas per square meter than the mid terraced B and C, despite having more exposed surface to internal volume ratio.
- On the top floor, flat T is an end flat, while R and N are mid-terraced. Flat T hosts a family of four, while flats R and N are single people households. The difference in consumption is evident, but also dependent on other factors that will be reviewed in Chapter 6 like the heating regime, preferred temperature and environmental concern.
- Flats D on the ground floor and T on the top floor have the exact same size, however, for being on the top floor flat T has more exposed area for heat loss through the roof.

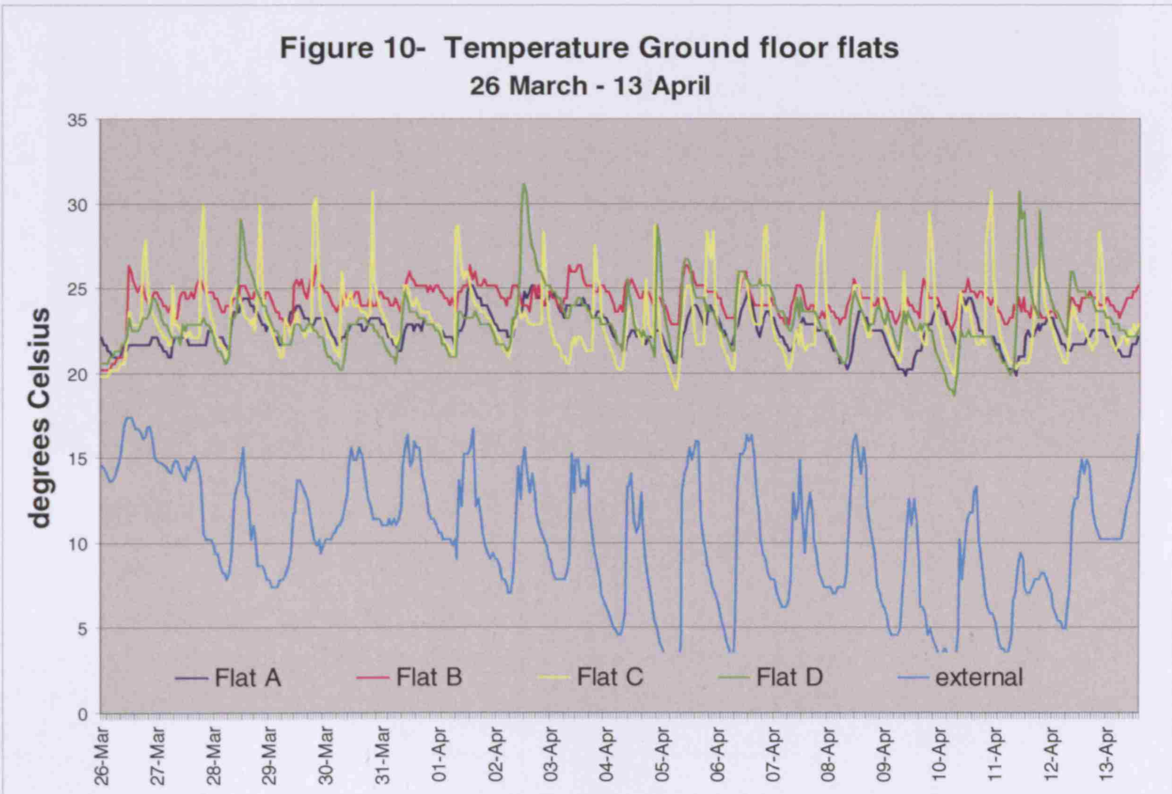


Ground floor flats (A, B, C and D) and upper levels (T, R and N) have different occupation patterns –ground floor tenants spend more hours at home- therefore the temperature and RH profiles, and its relation with the gas consumption will be analysed separately in the next pages.

Temperature – ground floor flats

The temperatures recorded in the ground floor flats are presented in figure 10. Ground floor flats and upper levels results are presented in separate graphs for clarity.

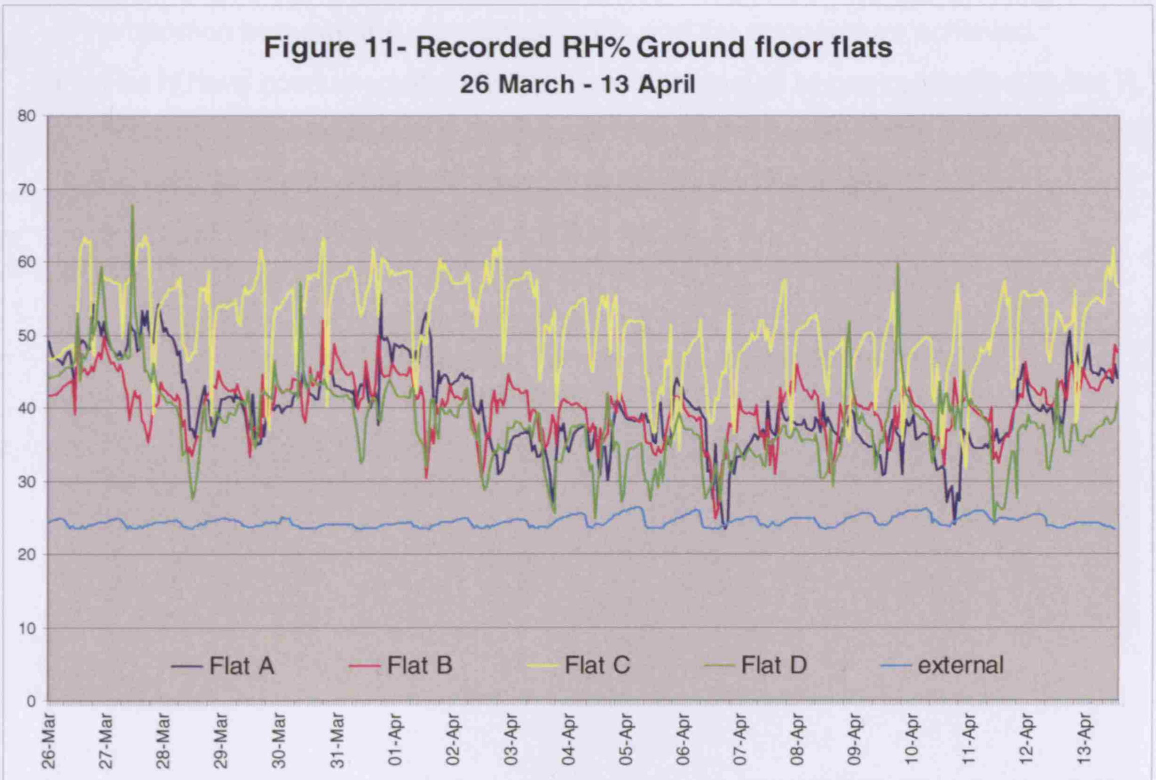
- There are two very distinctive trends in heating regimes. The first one, by flat A and B has a daily variation within a 5°C limits, while flats C and D have sharp peaks in both directions that span more than 10°C. It gets hotter than 30°C at some point during the day and colder than 20° during the night in these flats.
- The highest average temperature for this period was reached by flat B, followed by flats D, C and A, in that order. Flat B has the higher consumption per square meter from these four flats, and is also in average the hotter
- Conversely, there is an inverse proportion between the gas consumption and the temperature of the other three flats. This could be due to window opening habits leading to heat loss. Flat D, which has the largest exposed surface per internal volume ratio, an unfavourable quality in itself, is the most efficient of these four in keeping a comfortable temperature with the minimum energy consumption (and cost). This is possibly due to ventilation kept to a minimum.



Relative humidity- ground floor flats

Figure 11 shows the relative humidity data collected for the same period.

- The external values have a quiet daily variation, while the internal condition presents sharp contrasts due to internal activities.
- Flat C stands out as the most humid flat of all. Hosting a family of two adults and three children, moisture-generating activities such as cooking and bathing are done quite often. Possibly the flat is not ventilated as often as the others. In contrast, flats A, B and D tenants are only adults.
- The ventilation rate, whether the trickle ventilators are kept in the right mode, the frequency of moisture-generating activities being performed, and the external humidity levels have an impact in the level of humidity inside the flats.

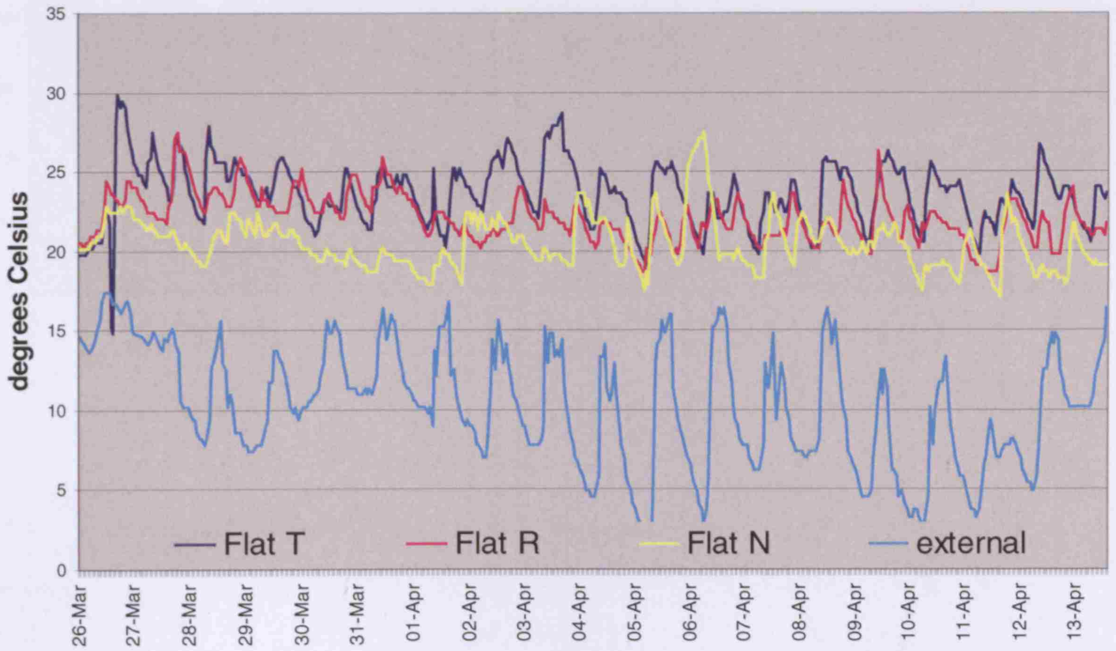


Temperature – upper level flats

The temperatures recorded in the upper level flats are shown in figure 12.

- There is a daily variation of almost 10°C in flats T and N, with flat T reaching the highest temperatures at 30°C on the 26th of March. There is an unusual event on this day, as the temperature dropped to 15°C and raised to 30°C within hours. This is probably due to windows left open when the flat was empty and suddenly closed and the heating raised to 30°C once the tenants arrived.
- Flat R has a quiet daily variation within 5°C limits.
- Flat T, followed by flats R and N, in that order, reached the highest average temperature for this period.
- Flat T has the higher consumption per square meter from these three flats (and the seven flats analysed in this exercise), and is also in average the warmer. For the other two, despite having the same size and exposed surface, there is an inverse proportion between the gas consumption and the temperature achieved.
- Flat N have consumed about three times the amount of gas consumed by flat R, however, it has been colder in average. Again, the cause of this is likely to depend on window opening habits leading to heat loss and heating set to high temperatures to recover indoor comfort levels.

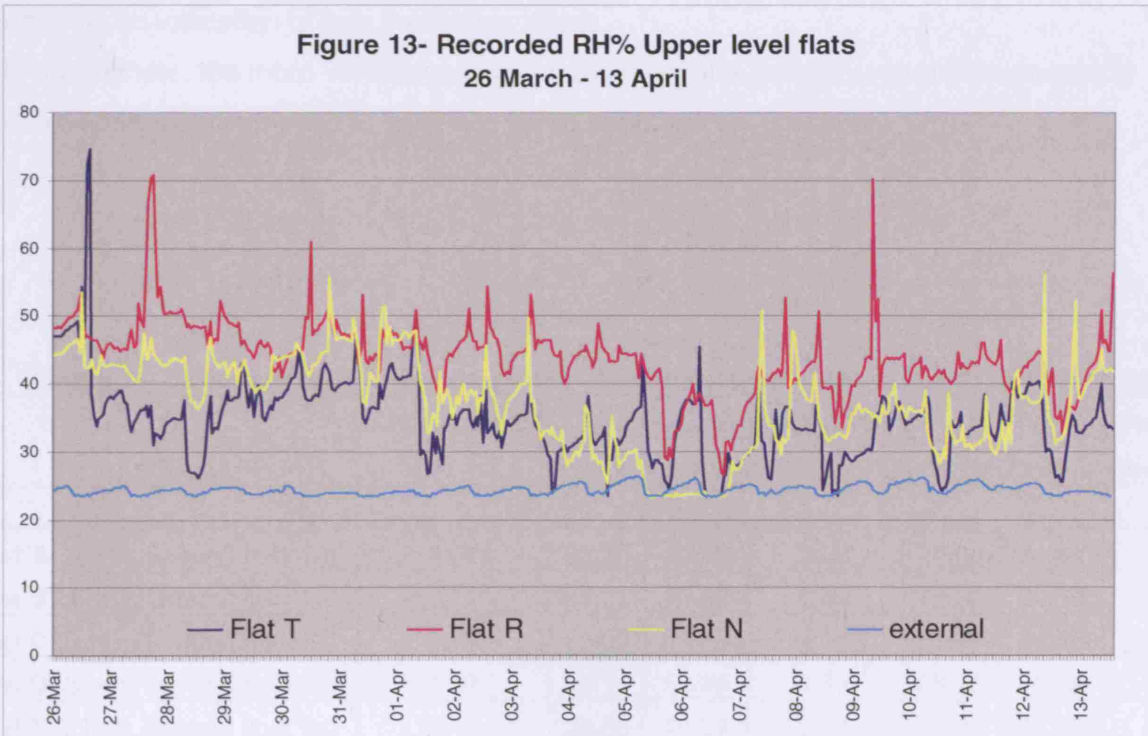
Figure 12- Recorded Temperature Upper level flats
26 March - 13 April



Relative humidity – upper level flats

The relative humidity data collected for the same period is presented in figure 13.

- Again, the external values have a quiet daily variation, while the internal condition presents deep variations due to internal activities and ventilation patterns.
- The unusual event of the 26th of March had also an impact in the humidity levels, as they rose steeply for flat T. Otherwise, flat T keeps a healthy humidity level of 30% in average.
- Flat R is the most humid flat on average. Although being a single person household, moisture-generating activities are likely to be performed more often in this flat or intensified by occasional events, such a visitors staying, parties, etc. It is also very likely that this flat is not ventilated as frequently as the other two flats. This idea is reinforced by low gas consumption: an airtight flat that is poorly ventilated does not lose heat (hence requires less heating) and moisture easily.



In summary

Figure 14 presents a summary of all flats monitored for the period 26th of March- 13th of April in terms of gas consumed per square metre, temperatures, relative humidity and standard deviations.

All flats achieve an average temperature above 20 °C, which is considered within acceptable comfort levels, keeping the gas consumption below the national average.

The standard deviation measures the value fluctuation, which is dependent of heating regimes and ventilation patterns.

The warmest flats tend to be the ones showing the highest consumption, unless this is altered by the levels of ventilation. The lower humidity values are and indication of higher ventilation habits in most cases, which at the same time has the effect of dropping the temperature and rising the consumption. Flat T and R, are examples of this: Flat T has a higher consumption to keep a temperature of 23.56 °C, and is likely to be ventilated more to keep a lower RH value. Flat R, in contrast has a lower consumption and high RH value, which is an indication of less ventilation rates.

In this climate, the more ventilation is given the lower the humidity value gets, requiring more energy consumption to keep the same temperature.

Figure 14- Summary for all monitored flats- Average values - 26th of March to 13th of April

Flats	Gas consumed per m^2	Temperature		Standard Deviation °C	RH %		Standard Dev. RH%
		Internal	External		Internal	External	
Flat A- 3 bed, Ground floor flat	0.54	22.50	10.29	1.07	40.04	24.38	5.89
Flat B- 3 bed, Ground floor flat	0.71	24.27	10.29	0.98	40.33	24.38	3.88
Flat C- 3 bed, Ground floor flat	0.47	23.00	10.29	2.11	51.59	24.38	6.37
Flat D- 3 bed, Ground floor flat	0.37	23.11	10.29	1.82	38.16	24.38	5.72
Flat T- 2 bed, Second floor flat	1.11	23.56	10.29	2.01	34.64	24.38	5.88
Flat R- 1 bed, Second floor flat	0.31	22.09	10.29	1.53	43.92	24.38	5.49
Flat N- 1 bed, Second floor flat	0.93	20.48	10.29	1.63	37.01	24.38	6.95

5.2. Electricity consumption

All flats in Boatemah Walk use electricity from the National Grid for lighting and to power their appliances. As they have all been fitted with low energy light bulbs, the electricity needed to power them will be reduced. In addition the passive stack ventilation used instead of mechanical fans should reduce consumption further.

Only the ground floor flats have a dual supply: from the national grid and from the photovoltaic panels installed on the roof. They benefit from the electricity produced by the photovoltaics only during the day, when it is produced. Therefore it is expected that their mains electricity consumption (and bills) will be lower than they would have been without this.

However, these systems can only help them reduce their consumption and costs. The major impact on their energy savings will come from their commitment to use it wisely and achieve an optimum consumption level without compromising their comfort standards.

Figure 15 - electricity meter on a ground floor flat

On the first visits all available tenants were reminded of the benefits of limiting the use of electric powered appliances and lighting to their essential needs. Some of the ground floor tenants were not quite sure when the 'free electricity' was being produced, so they were reminded that the electricity from the solar panels is only produced when there is daylight, and to reassure themselves of this, they just needed to have a look at the first number on the reading board installed in one of the stair cores. They were also encouraged to use their electric powered appliances (washing machine, vacuum cleaner, iron, hairdryer, etc.) during the day.

Figure 14 shows the monthly electricity consumed from the mains for all flats monitored (see appendix A for flat location and layout). This data has been collected by doing regular readings on every household's electricity meters.

The electricity consumed has decreased considerably for some of the flats, like flat A and flat T. For flats B, C and D on the ground floor, the consumption decreased between February and May, when it started increasing again towards July. Flat A and T had an unusually high consumption in March, possibly due to the presence of guests.

The one-bedroom flats have different patterns of consumption, as flat N is constantly decreasing and flat R is rather random. Single people, who work during the day and do not spend much time at home, occupy those flats.

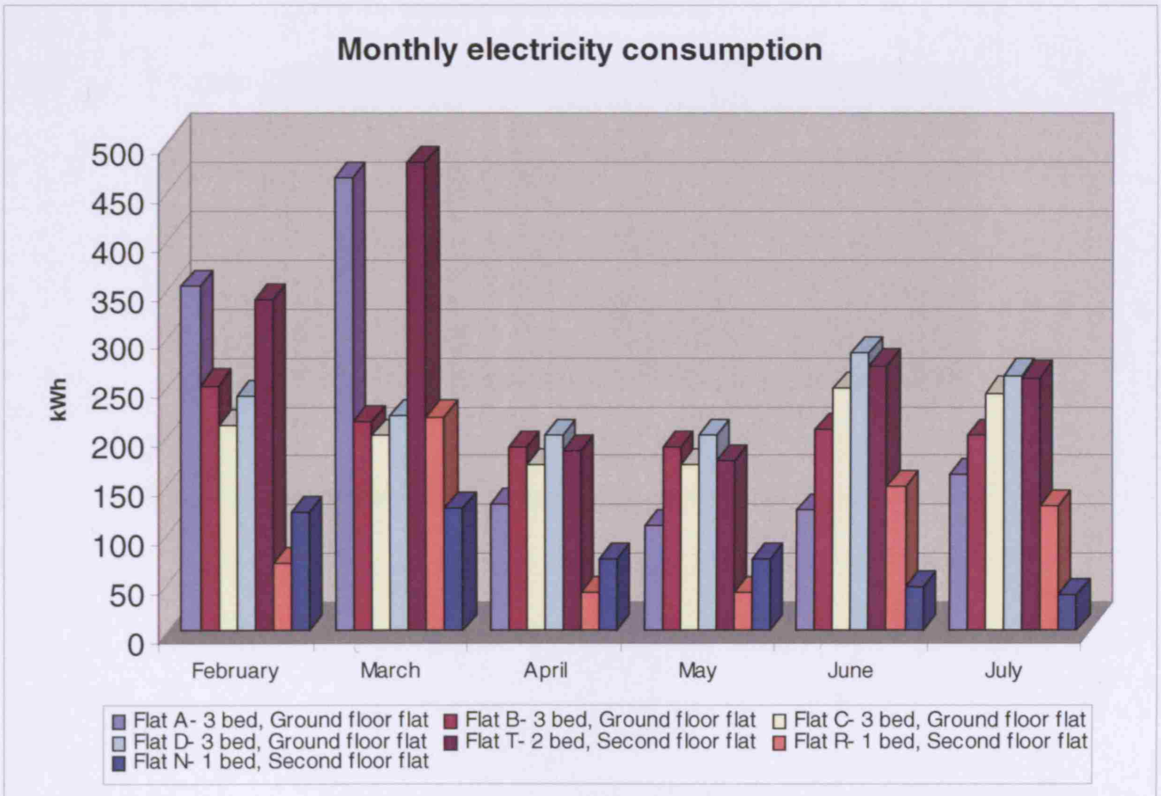


Figure 16 – Monthly electricity consumption from mains- February to June

The UK average domestic electricity consumption according to the DTI[3] is 3,300 kWh/ household, which also takes into account homes that have electric heating. BedZED target for electricity consumption was 2,700 per household. Considering the above, and the fact that Boatemah Walk requires electricity only for lighting and appliances, Katharine

Scott[4] assumed Boatemah Walk's annual consumption to be 3,000 kWh/household. This amount, in the case of the ground floor tenants would come from two sources: mains electricity and photovoltaic production.

The six months of monitoring carried out include summer and winter months thus are representative for half year consumption. Using this data, a projected annual consumption from mains can be assumed for every household as shown in figure 17.

The ground floor flats (A, B, C and D) have all consumed below 3,000 kWh from mains, however the contribution from photovoltaic roof (which is yet unknown) needs to be added. Flats T, R and N have different household sizes. Expectedly flat T (four people household) exceeded the projected amount and flats R and N (one person households) are well below the mark.

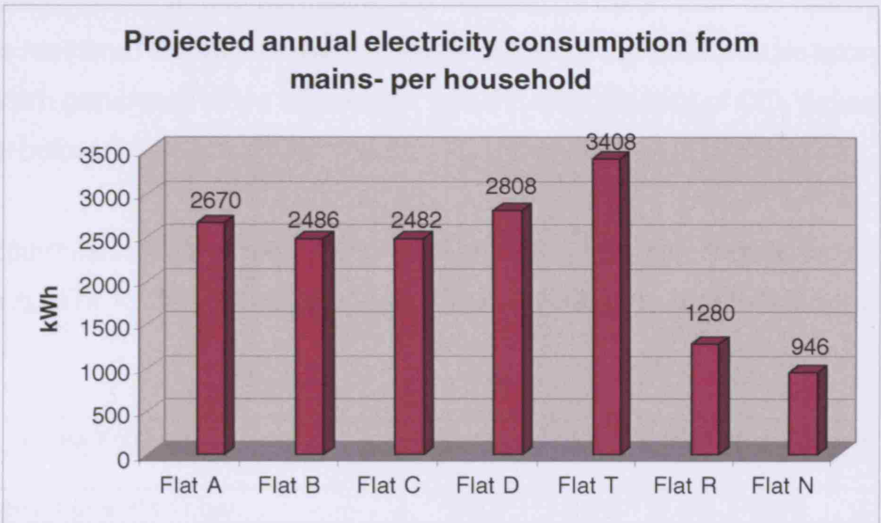


Figure 17 – Monthly electricity consumption from mains- February to June

5.3. Performance of photovoltaic panels

When the system was designed, it was specified to include export meters to sell the surplus electricity to the National Grid as it is being generated. However, the meters were not installed once the building was completed.

Almost a year after completion, the negotiations between EDF energy and Lambeth Energy Management are under way to have four export meters installed, one for each ground floor flat. The value of the excess electricity going to the national grid is to be agreed between the parties, and will be paid to Lambeth to be channelled back into other environmental projects.

The only data available at the moment is the information taken from the reading board that indicates, in real time, the instantaneous power output of the photovoltaic array, the total amount of kWh generated since installation and the total amount of CO_2 saved, as shown in the figure below.

The roof accumulated output was 12005 kWh on the 21st of July, thus is very likely that the predicted output of 13.327kWh a year, calculated in Katharine Scott's study (see 4.4) will be met.

Information on the reading board	03-Dec	04-Feb	26-Mar	05-Apr	08-May	29-Jun	21-Jul
Total energy being generated now	2.37	0.77	0	0.31	0.43	1.49	0.06
Total energy generated since installation (kWh)	6634	7002	7825	8518	9232	10999	12005
Total carbon dioxide emissions saved CO2	2852	3010	3364	3661	3969	4729	5162

Figure 18- Information taken from the reading board

In addition, the amount of electricity used by the ground floor tenants from the National Grid during the last six months is also available. This is the electricity that has been used when there was no production from photovoltaics.

There is no indication of how much of the electricity produced by the roof has actually been used by the tenants, or what percentage from the total consumption this represents. However, the whole roof production data, and the known demand from the Grid plotted in the same graph (Figure 19) gives the following information:

- As expected, the roof electricity production increases, as the days get longer towards the summer months. The production peaked in June, where it is very likely that the roof production would have supplied close to the entire demand of the building.

- The electricity consumed decreases slightly towards the summer months, as less energy is needed for lighting.

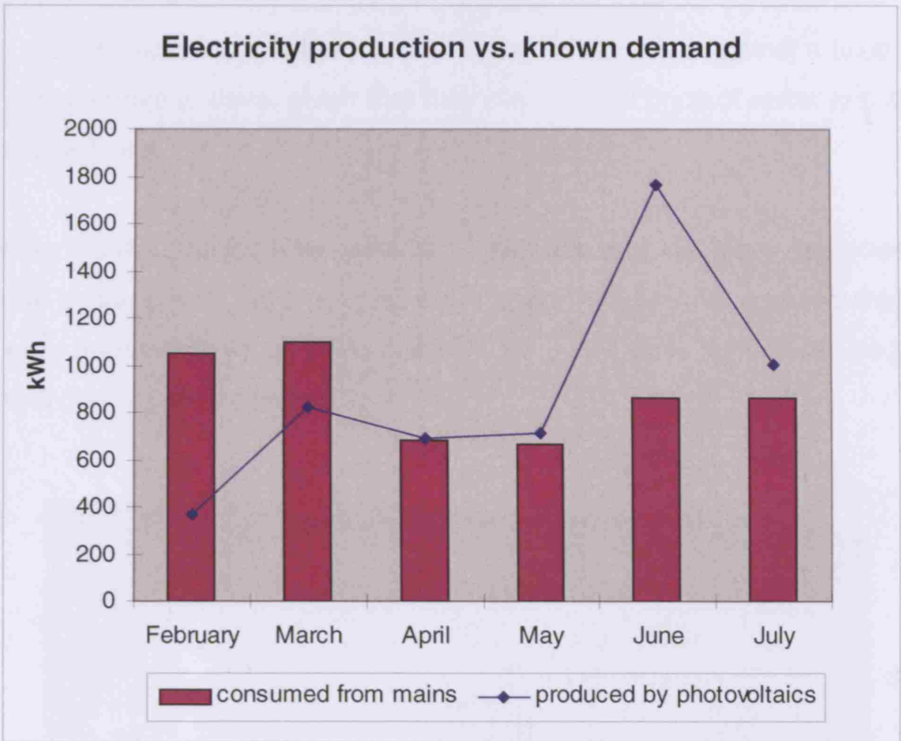


Figure 19

5.4. Water consumption

All tenants currently benefit from water savings, as the water used to flush their toilets comes either from rainwater or from mains backup water paid by Lambeth council. Therefore their water usage is expected to be considerably reduced, given that the water needed to flush toilet is usually a large proportion of the total consumption.
Moreover, most tenants have water meters for the first time, as against a fixed tariff. This is usually an incentive to save, given that they pay the real price of water and exactly what they have consumed.

To take water meter readings was easier than with gas and electricity, because the meters are all in one place, out on the street. No permission from tenants was required. Meter readings were taken once for all flats on the 21st of July thus is considered as an indication of the annual consumption reading.

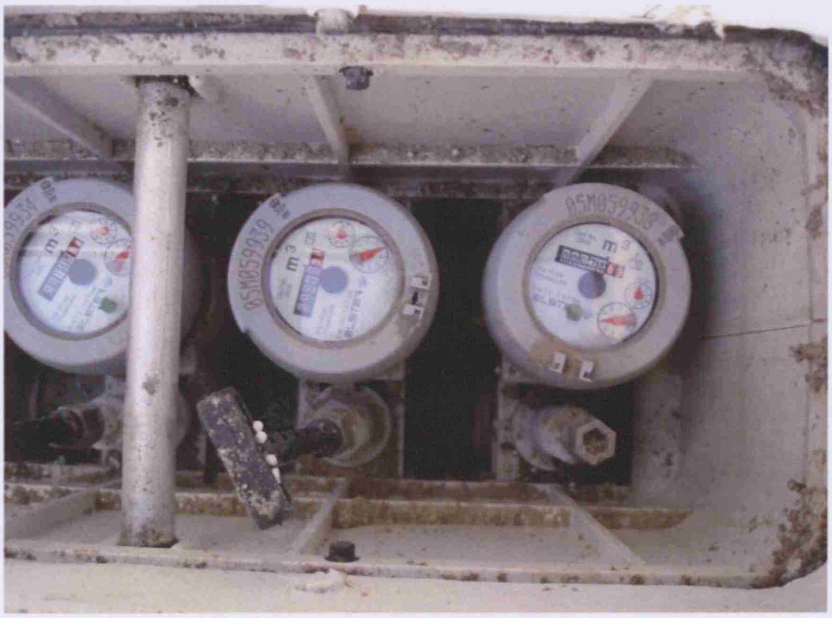


Figure 20- Water meters

The average daily UK consumption is 150 litres per person, including toilet flushing.
The tenants' metered consumption in Boatemah Walk excludes toilet flushing, which is about 50 litres in an average household. Therefore an average of 100 litres per person per day is expected.
To make the data easy to compare, the collected data in annual m^3 per household has been converted in litres per person a day.

The chart below shows the water consumption for Boatemah Walk tenants, where the following can be noted:

- Flat N has a leakage problem that is due to be fixed. The problem was found when the tenant received an expensive bill for an amount of water he could not have possibly used.
- The possibility of leaking pipes to other flats is uncertain. If these numbers reflect the real consumption, it is definitely quite high.
- Only 3 of the flats (occupied by single people) have consumed below 100 litres.

Many possible explanations can be assumed for this high consumption. One is the fact that they got used to the previous payment method they had with fixed price every month, and just continued with the same patterns of consumption when they moved to these flats. They have received their first bill late last year, and possibly started using less water after that. As we have a general annual reading it is not possible to know if they have consumed less after their first bill arrived.

Another explanation is based on the knowledge about the 'free' water they get from the rain. As they are certain that their bills will be lower anyway, this could encourage higher consumption.

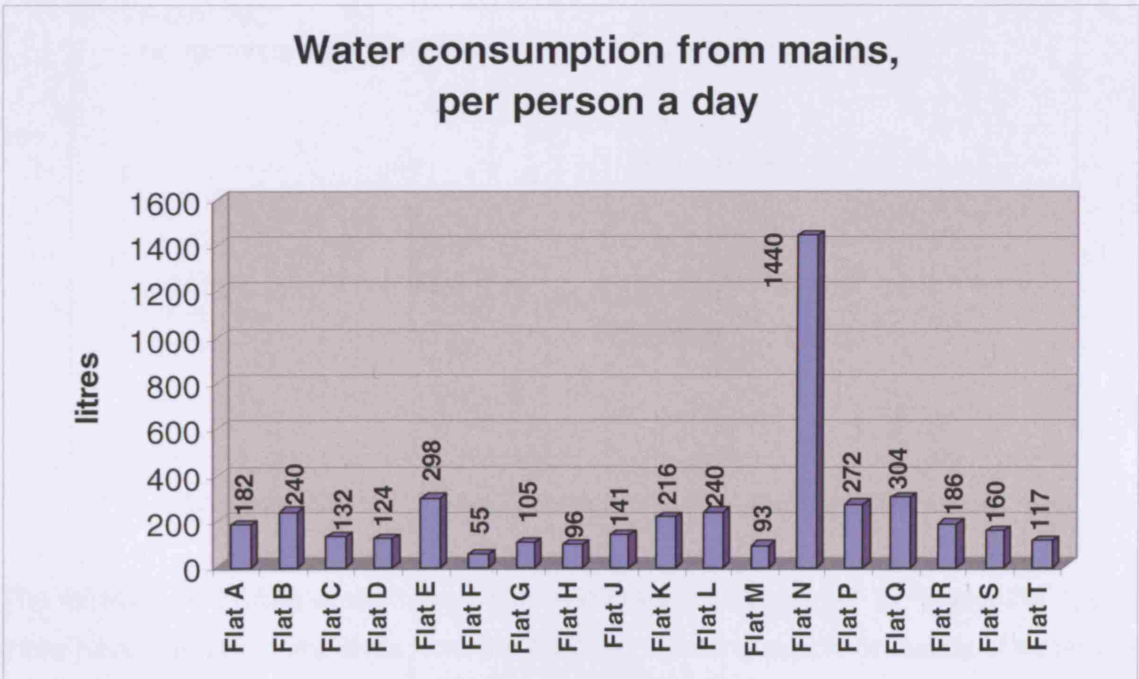


Figure 21 – Water consumption

5.5. Performance of rainwater recycling system

The projected figures for water saving when the system was installed were based on two factors: the use of low water dual flush WCs and the use of rainwater for WC flushing. Before occupation, it was estimated that 220 m^3 of water would be saved from WC specification and a further 176m^3 from using rainwater on site according to Cath Hassell of ech_2o[5].

The first figure was calculated assuming 6 WC uses a day. For a normal 6-litre WC, the daily amount would be 36 litres. Using the dual flush WC and assuming four uses for half flush (2.5litre) and two uses for full flush (4 litre) the amount would be 18 litres. There is an 18 litre saving per person per day only for the type of WC specified.

The amount of water saved on a year, for a population of 33 people currently living in the building, would be around 216 m^3

For the second figure it was assumed that an 80% of the total water used for toilet flushing would come from the rainwater, therefore 172 m^3 would be saved in addition.

The figure below illustrates the volumes of water needed for both 'normal' practice and the projected Boatemah Walk consumption.

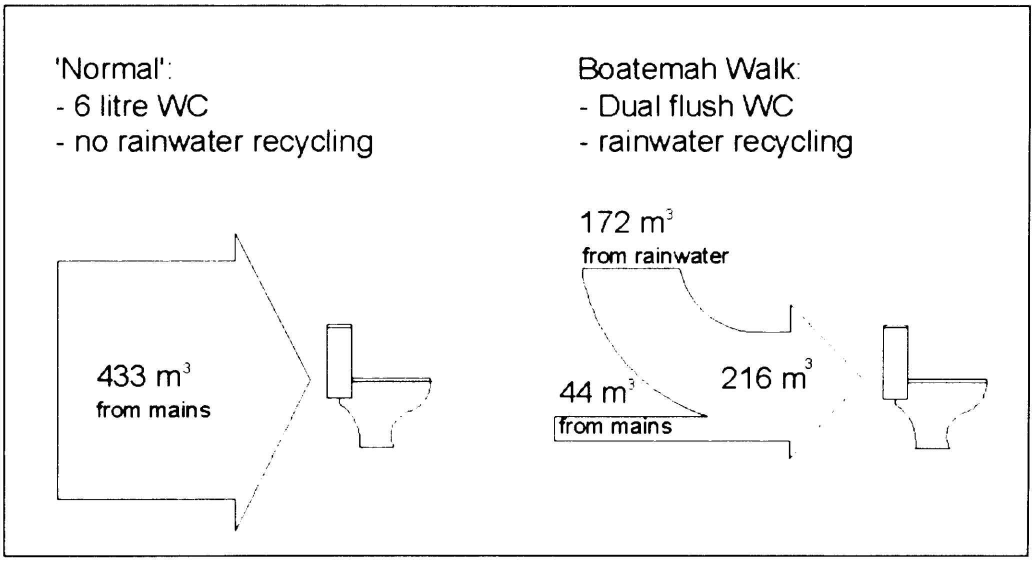


Figure 22- Compared toilet flushing volumes for normal practice and Boatemah Walk

The rainwater recycling system has been working since installation in August 2005, and there have been no complaints from the tenants regarding supply or quality of water used for toilet flushing. The system has mains water back up that fills the header cistern whenever rainwater is not available, therefore there will always be available water for toilet flushing, and it would remain unnoticed whether there is rainwater or not.

Site visit

On the 21st of July the site was visited to verify the system's operation. A detailed report produced by Cath Hassell can be found in the Appendix C.
This is a summary of the findings:

- There was only one meter that shows the amount of water coming from the mains backup, showing 212 m^3 used since installation in August 2005. This is close to the total annual amount needed for toilet flushing, according to the previous projections. However, the tidemark into the cistern indicates that it has been filled before at a level reserved for rainwater only. (When there is rainwater the cistern gets filled up to approximately 90% of its capacity, while in the absence of it, the mains backup fills only up to 50% of its capacity as a standard)
- No meter was installed to measure the amount coming from the underground tank (rainwater).
- The header cistern did not present a biofilm, which usually appears when it is filled with rainwater regularly. Instead, there were chalky deposits, which suggest that it has been supplied mostly with mains backup.

Figure 24- Header cistern

Mains backup meter showing 212 m3 used

Rainwater pipe from underground tank, no meter installed

Figure 23- Rainwater and mains backup pipes

It was specified on the design to include a meter for the rainwater coming from the underground tank, however it was not installed. As this was a design and build contract, both contractor and employers' agent have overlooked the absence of this meter. Without this meter it is not possible to find out how much rainwater has been used, however, the absence of a biofilm indicates that most have been supplied from the mains backup.

On the 8th of July two technical staff from Sandwood contractors went to Boatemah walk to check the performance of the system, following recommendations from Cath Hassell's report. The contractor's report can be found in the Appendix C.
They inspected the underground tank and found that the pump was working correctly. Inside the tank there was only 225mm of rainwater. The underground water level indicator in the pump controller cupboard confirm this, showing the tank to be at a 6% of its capacity. They installed a new meter for rainwater supply to the header cistern for future monitoring.
They suggested that the low levels of rainfall are the reason why the system has been running from mains water, however, the rainfall data for the South East of England suggests otherwise.

Rainfall Potential

According to the rainfall records for the south East of England, the system could have run with rainwater only. Although the rainfall levels have been well below average for the past year, they would have been sufficient to supply the projected demand. Moreover, the underground tank and header cistern combined storage capacity of 17m^3 would have been sufficient to keep enough water for almost a month's demand in dry conditions.

According to previous calculations, the average monthly consumption for toilet flushing for the whole building would be approximately 18m^3. The figure below shows this demand contrasted with the Met office's[6] actual rainfall data for the south east of England that would fall on the 650m^2 Boatemah Walk roof, according to this calculation:[7]

Roof area (m^2) x rainfall (m) x 0.85 (roof drainage factor) x 0.85 (average filter efficiency)= Available rainwater

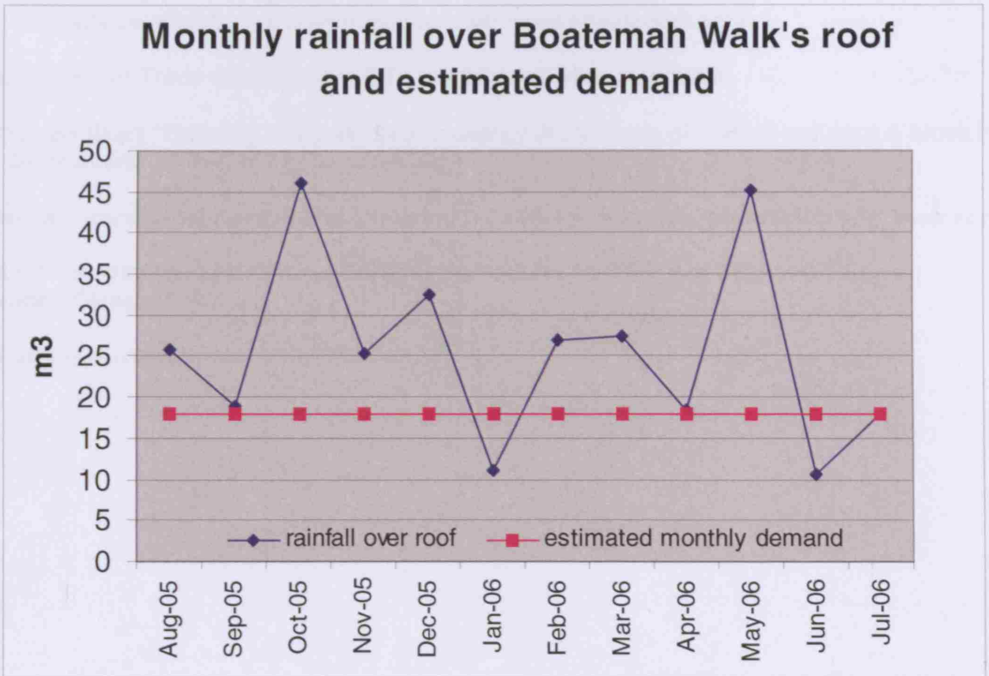


Figure 25- Monthly rainfall over Boatemah Walk's roof and estimated demand

As this rainfall data corresponds to a wide region, it is uncertain whether the local rainfall in the Brixton area has been comparable.

For this reason, it is not possible to determine the reason why so much mains backup water was used. The newly fitted meter will allow a precise monitoring in the future.

[1] External temperature data taken from the London Air Quality Network, available at: www.londonair.org.uk

[2] More details on HOBO data logger available at: www.onsetcomp.com

[3] Department of Trade and Industry (DTI) available at www.dti.gov.uk

[4] Katharine Scott "Building integrated solar energy at the scale of a small residential block in the UK" MSc Dissertation, University of London, 2005

[5] Ech₂o environmental consultants designed the system, for more information see: www.ech2o.co.uk

[6] Met Office, Weather and Climate, Monthly summaries for 2005 and 2006, available at: www.metoffice.gov.uk

[7] Following conversations with Cath Hassell

6. Tenants Survey

In order to find out the tenants general feel regarding the building and relevant consumption patterns, a questionnaire was prepared addressing various topics, from the perception of comfort in their flats and their patterns of consumption to their opinions about the building where they live and the systems installed. A copy of the questionnaire can be found in Appendix D.

The survey was carried out in form of a direct interview with the consent of some of the tenants. All the ones that did not answer received a copy of the questionnaire through the post including a return envelope. In total, responses from nine households were received, including all 3 and 2 bedroom flats, which correspond to half of Boatemah Walk households, and approximately 70% of its population.

6.1. Population

The total population in Boatemah Walk is estimated as 33 people. This is assuming that the households that did not respond, and live in 1 bedroom flats, are single people households. The largest age group is the one aged 16 to 65; there was nobody older than 65 among the people interviewed and only 4 households have children. The figure 1 shows the age distribution.

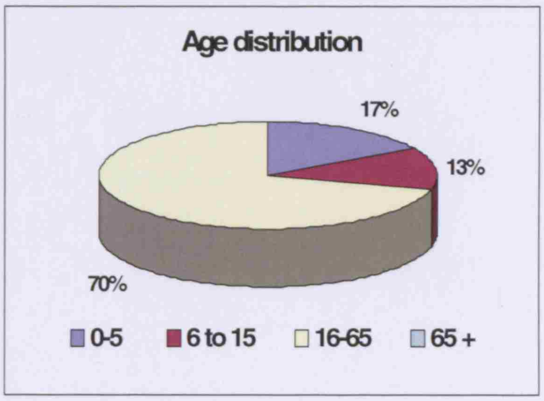


Figure 1

6.2. Flat occupation

The tenants were asked when their flats were occupied on a typical weekday. Somebody thought giving that information could be security risk and was reassured that it was to be used only for academic purposes. As shown in the chart, the flats are mostly occupied before 7 am and after 5 pm. All ground floor flats are usually permanently

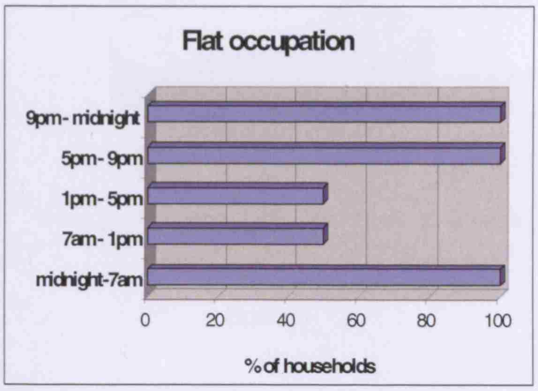


Figure 2

occupied, as predicted when being assigned to benefit from photovoltaic electricity.

6.3. Temperature and humidity

When asked how warm or cold their flats feel, the tenants mostly responded it was OK, this confirms the fact that they can adjust the temperature to their liking. A couple of families with children like the house warm (and gave that answer), so it is clear everyone interviewed can adjust their homes temperature to their liking.
Likewise, the humidity seems OK for most of the tenants interviewed, except the couple of families that consider 'warm and dry' to be the optimum. The humidity created by cooking and bathing can be dissipated rapidly and does not cause discomfort to tenants in general.

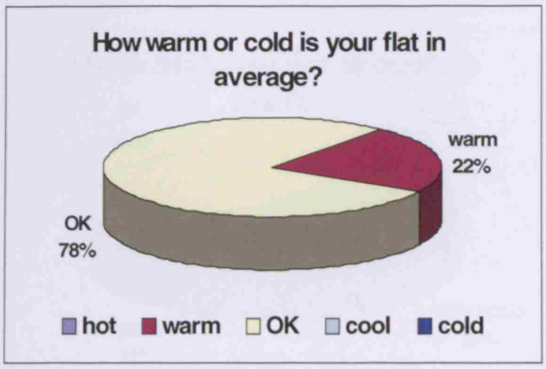


Figure 3

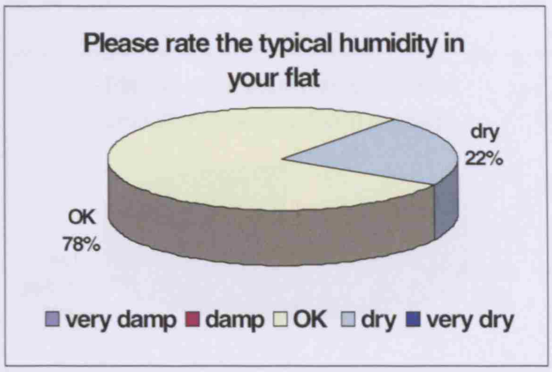


Figure 4

6.4. Daylight quality

Regarding the daylight quality, most tenants were very appreciative of daylight quality in their flats. A young mother praised the fact that kitchen and living room are linked by glass doors, which allows light to flood through the flat and raise light levels in the kitchen, which is north-oriented. Somebody compared this to his dark and mouldy previous flat, and said he felt very lucky to be in Boatemah Walk. The largest windows are south oriented, which enhances daylight intensity.

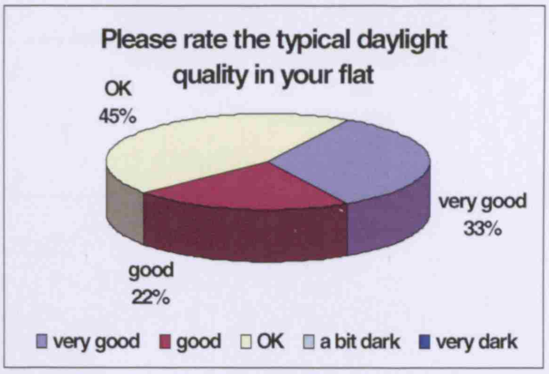


Figure 5

6.5. Air quality

In terms of air quality in the flats, the responses were also positive, as can be seen in figure 6. The tenants know that trickle vents need to be permanently open, so they get adequate ventilation during winter without opening the windows. During the summer, the upper level flats keep the doors that lead to the balconies opened, but the ground floor tenants prefer to open the windows only a few degrees in a locked position for security reasons.

In general they prefer to open the south oriented windows that face the gardens to avoid any pollution (which they consider mild or tolerable) from Brixton Road.

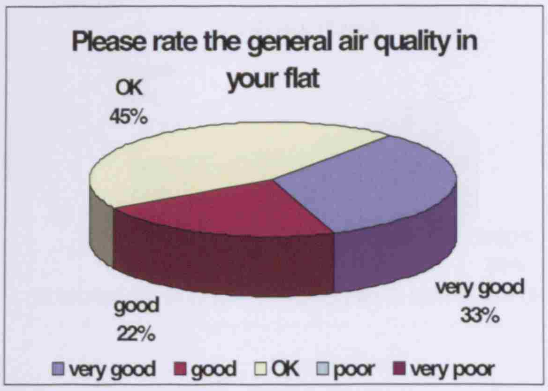


Figure 6

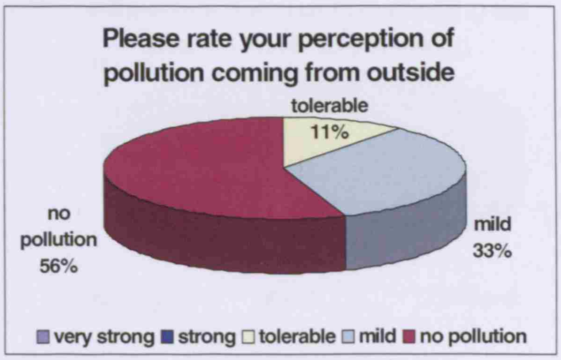


Figure 7

6.6. Noise

The tenants were asked to rate the external noise levels they perceive while in their flats during day and night time. During the day most tenants found the noise tolerable, referring to the traffic noise from Brixton Road. Some emphasized the difference between both sides of the building: "It is much quieter on the gardens side".

During the night, the source of 'strong' noise for some tenants is due to youngsters gathering on one side of the building with skateboards and scooters.

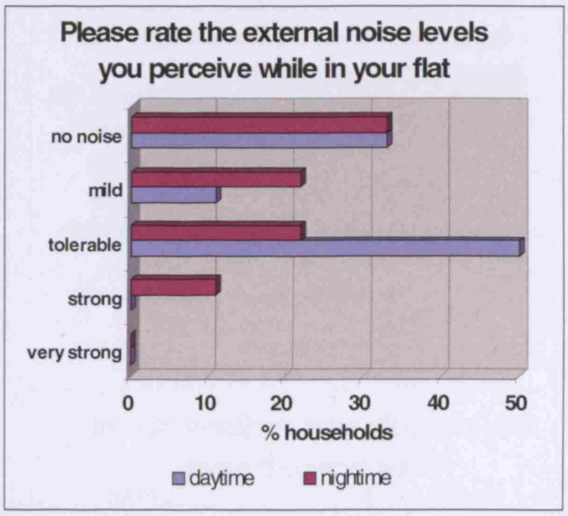


Figure 8

6.7. Communal lighting

This question was asked only to upper level tenants who are the users of the communal staircase. Most tenants rated the quality of lighting in the staircase as bright and adequate, as shown in figure 9. The staircases are considered to have very good daylight levels and to be well lit at night by low energy lights that are activated by movement sensors. It means that the lights are on only when there are people using the staircase, saving energy.

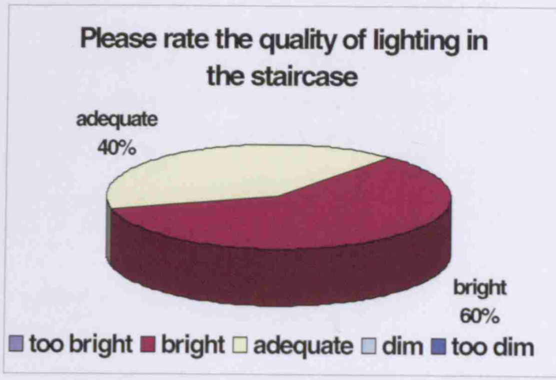


Figure 9

6.8. Thermal comfort

In terms of thermal comfort, all households found it OK to control the heating levels to their liking, with the upper flats tenants mostly using the 24-hour automatic clock incorporated in their boilers, and the ground floor tenants doing it manually, whenever they arrive and leave the house.

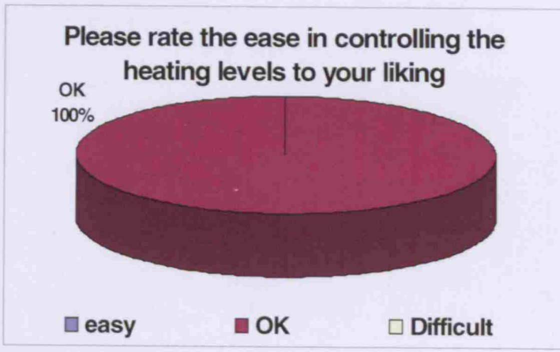


Figure 10

When asked which hours do they have the heating on, the tenants answers didn't follow exactly the flat occupation patterns (see 6.2) Many households switch the heating off while they sleep, they switch it on for the morning hours, and off into the afternoon once the flat achieved a comfortable temperature, regardless of their presence.

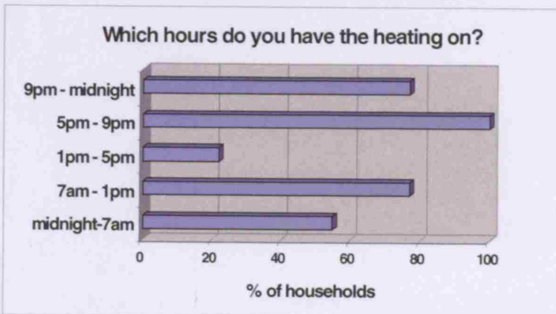


Figure 11

6.9. Environmental behaviour

The following questions could sound meaningless if judged separately, but as a whole can help us identify the little habits that form patterns of behaviour and have an impact on the gas, electricity and water consumed.

The following four questions refer to the tenants' preferences in cold weather:

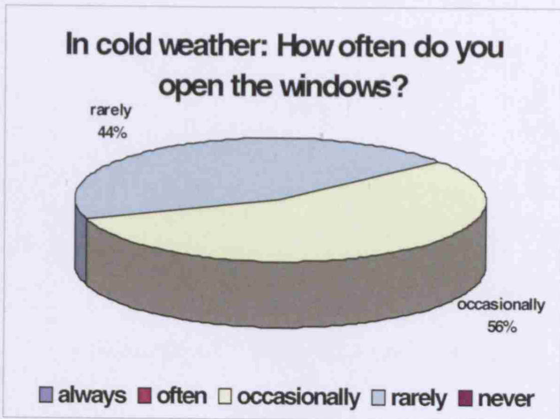


Figure 12

How often do you open the windows?

As shown in figure 12, the tenants interviewed do not tend to open windows often, as most answers were rarely and occasionally. They are aware of the heat loss caused by it, and the trickle vents role in providing enough air changes. They open the windows for short time in case they need to evacuate smoke from burnt food or dissipate dampness from bathing.

Do you wear more clothes indoors in cold weather than in warm weather?

This question, together with the next one, aims to cross- examine the indoor temperature preferences. As most answers were often and always, it is clear that the tenants interviewed prefer dressing warmer and save energy rather that recreating summer temperatures indoors. However some do like very warm flats.

How warm do you like your flat?

The preferences are clear, and in connection with the previous answers. Most households prefer the temperatures on the low to mid twenties, while a few like it warmer, especially families with small children.

Do you lower the heating at night?

Most households do, as it allows them to sleep better, some tenants say they do it to save money.

Do you cover the pots when cooking?

Apparently a trivial question, but a great amount of gas can be saved from having the

Figure 13

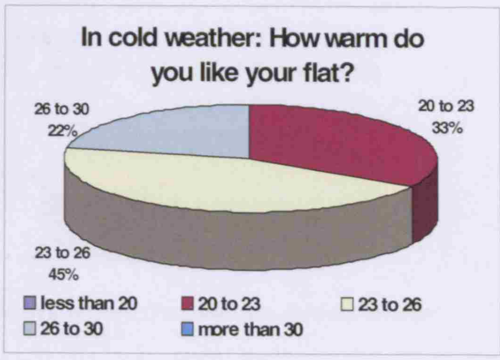


Figure 14

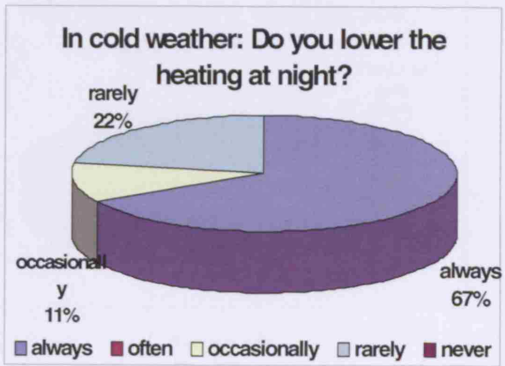


Figure 15

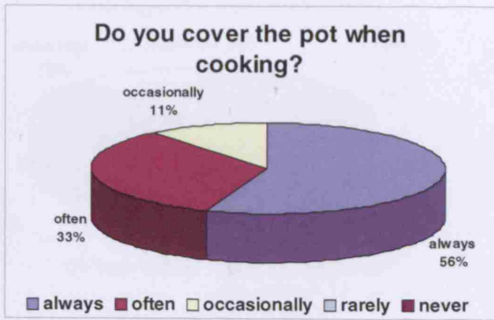


Figure 16

habit of covering the pots. Most people do it because 'it cooks quicker', and also because of the money saving involved in energy saving.

When leaving a room unoccupied, do you switch off the lights?

This is one of the first things children are taught in relation to energy saving. Most interviewed tenants are very aware of the importance, and the ground floor tenants know they have to pay for the lighting when there is no daylight, therefore are most careful with their night time consumption.

Do you switch the TV off with button instead of the remote control?

Some tenants said that they did not know the difference, and after being explained about the energy consumed when having electric appliances in stand by, their answer was: always. It is not certain if that is what they have been doing or what they were planning to do in the future. Either way it is a good intention.

How many hours a week in average do you spend ironing?

All tenants spend only one hour or less ironing.

How many hours a week do you use a hairdryer?

Most tenants use it less than an hour, a quarter of interviewees never use it, while some do it seasonally (only in cold weather).

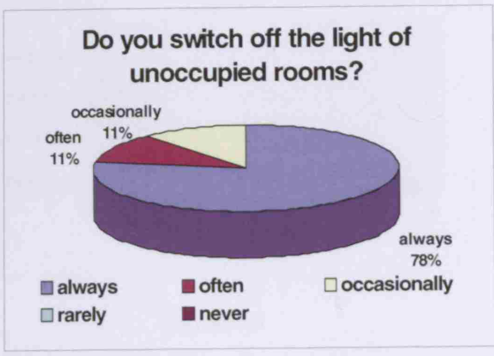


Figure 17

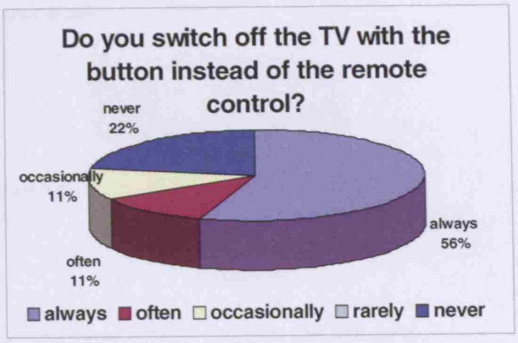


Figure 18

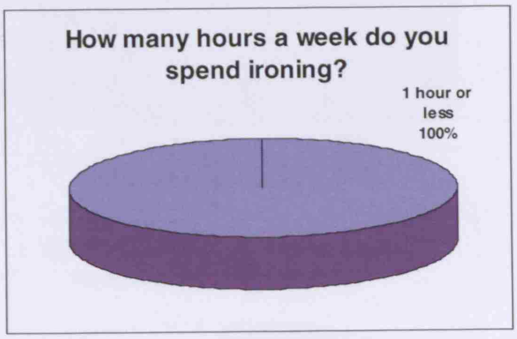


Figure 19

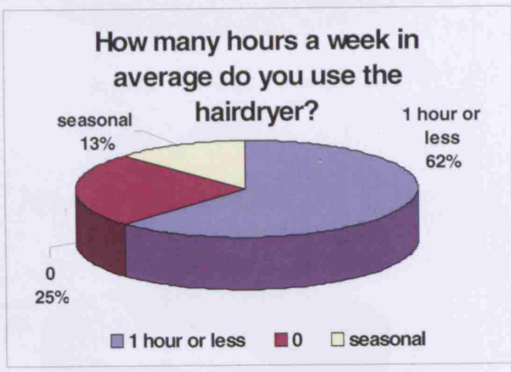


Figure 20

Are your electric appliances energy efficient (A-rated)?

As can be seen on the bar chart, only a couple of households had A- rated washing machines, by chance as they did not know of their qualities. Most tenants had none or did not know what the difference was.

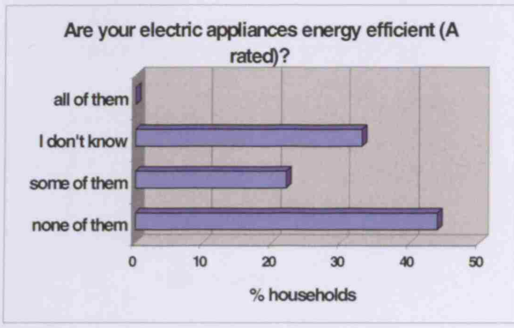


Figure 21

When you use the washing machine, do you ensure it is fully loaded?

A great deal of energy and water can be saved washing full loads fewer times rather than few clothes more times. Most households are aware of this, and try to wash fewer times, as shown in the pie chart.

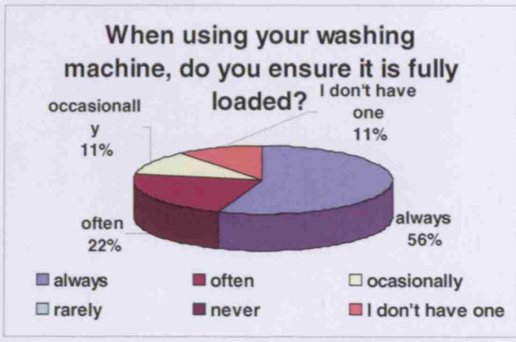


Figure 22

In average, how many times a week do you use your washing machine?

Most households interviewed wash just one or two loads a week, while the families with children do it almost every day.

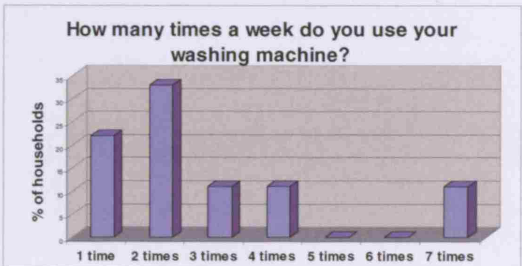


Figure 23

When washing dishes, do you use cold or warm water?

Most people change seasonally, using warm water when it's cold and cold water when it's warm, some use always warm water.

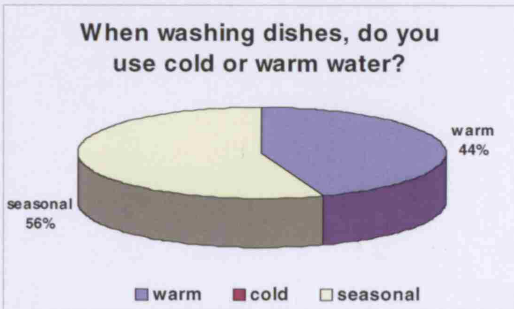


Figure 24

When washing dishes, do you do it under running water?

There is a much divided set of answers, showing that half of the households are concern about water saving, while the other half are not. As they pay for the water they use, most said that they would be more careful in the future.

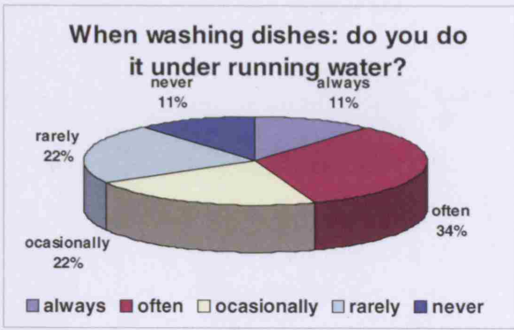


Figure 25

In average, how many times a week do you fill the bath?

Most households fill the bath 3 times a week, especially during cold weather. Families with children do it every day, regardless of the season.

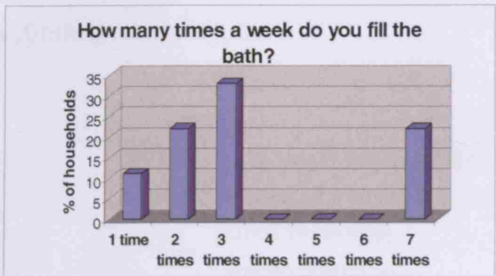


Figure 26

In average, how many times a week is the shower used?

As this question was not per person, but as a total, larger households have more usage, and once a day per person is the average use.

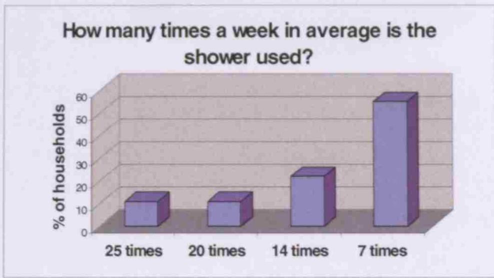


Figure 27

In average, how long do people in your household take to shower?

Most tenants take quick showers of 5 to 10 minutes, while a few like to spend up to half an hour under the water.

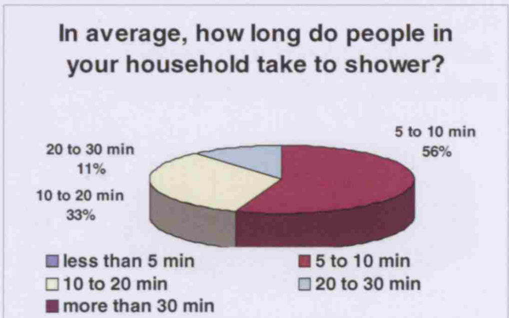


Figure 28

The following two questions are for ground floor tenants only:

Do you use your electric appliances during daylight hours?

Most tenants are aware of the benefits and do it whenever possible.

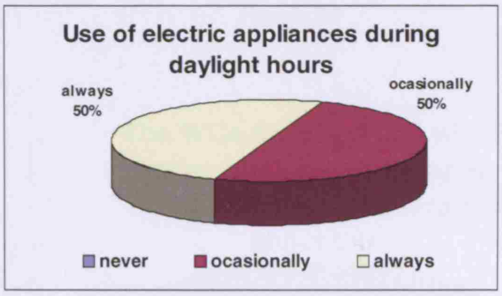


Figure 29

How often do you look at the reading board?

Half of the interviewees never look at it, from which some did not know of its existence. The other half does it always or occasionally.

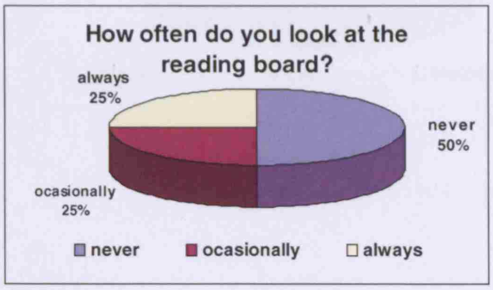


Figure 30

6.10. Perception and use of rainwater recycling

Please rate your perception about the use of rainwater for toilet flushing

When asked about their perception on rainwater recycling, there was a unanimous approval. Most tenants have water meters for the first time as against paying a fixed standard price, therefore are finding it expensive in comparison and the savings they get as a result of rainwater recycling are most welcome. Only one person pointed out the environmental benefit of the system.

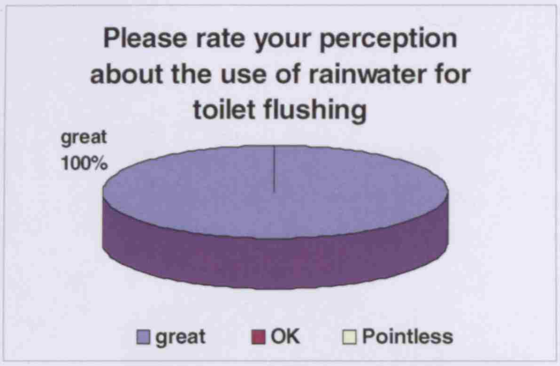


Figure 31

Please rate the quality of the water used to flush the toilets

The quality of the water used is considered just right by 100% of the interviewees. Ideally, this would be due to the rainwater filter working properly. However, it could also be due to potable water from the mains backup supplying the cistern, in the absence of rainwater.

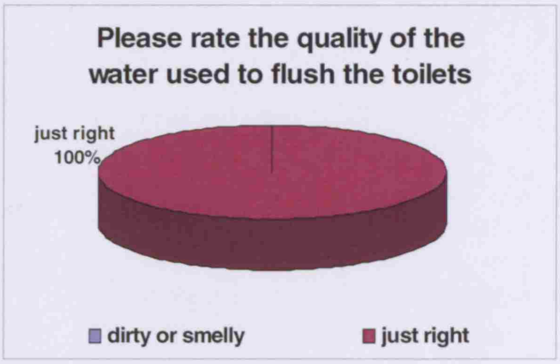


Figure 32

As a water saving measure, the toilets are equipped with two options of water discharge. Please rate your perception about this.

Again, there is a unanimous approval on this matter. Some are aware that they pay none of the water used to flush toilets; some think it is free just when it rains. The latter are more appreciative about having the option to save water, feeling that the rainwater collected should be made last longer.

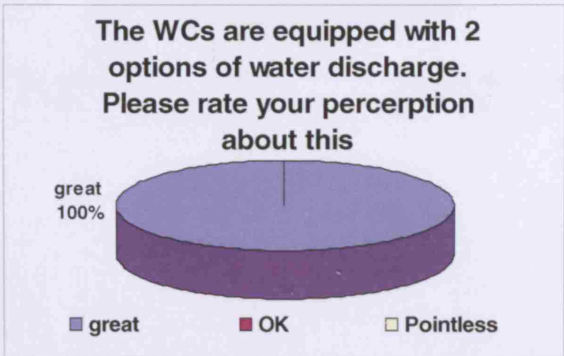


Figure 33

6.11. Perception of photovoltaics clean electricity production

The solar panels on the roof provide free electricity for some residents. Please rate your perception about this.

Most tenants think it is great, especially all ground floor tenants, who are the ones benefited. For some tenants in the upper levels it was just OK.

One of them expressed her disappointment to the fact that they did not benefit from it.
In general, they were curious about how the electricity was being produced from the sun.
A basic explanation was given.

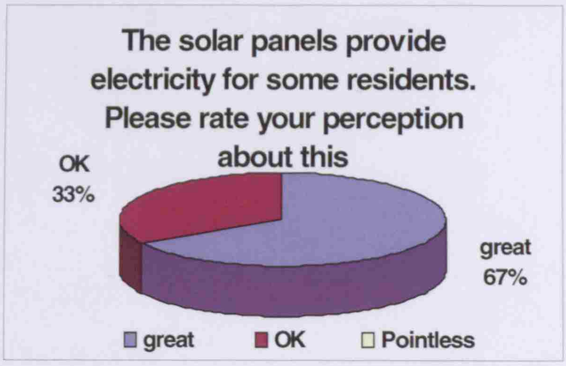


Figure 34

6.12. Compared cost of energy use

When asked to rate their current energy bills compared to their previous flat, most tenants found that they pay less, some pay about the same and a few pay much less.
The 'no bills' percentage applies only to gas in the upper level flats. Although they are supplied with gas, none of the tenants interviewed in the upper levels have ever received a gas bill.

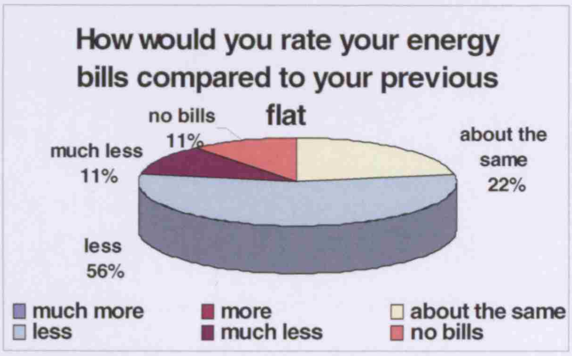


Figure 35

Some of them have been trying to set up an account to start paying but gas suppliers do not recognise them.
Ground floor tenants have all been supplied and billed by British Gas.

6.13. Overall evaluation of the building

The overall evaluation is quite positive, with most tenants rating the building as excellent for their wellbeing and comfort. Most tenants find the condition of this building much better than their previous accommodation.

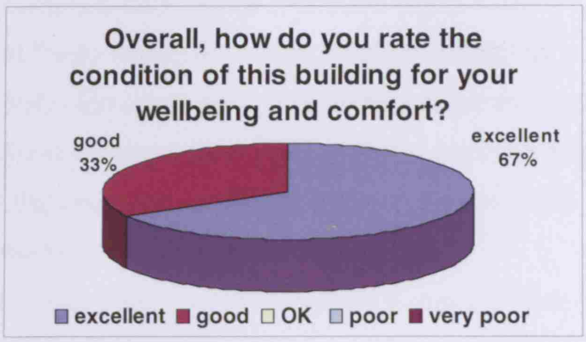


Figure 36

The questionnaire has two main categories: the tenants' evaluation of the building and the impact of energy consuming behavior on the building performance. Every answer has been weighted to show a summary of them all. The summaries are presented on the Appendix D.

Some tenants shared these experiences during their interview:

A family used to live in the Brixton area for a long time, until a member of their family got attacked in the neighbourhood. They moved out thinking they would never return. When they got offered a flat in Boatemah Walk, they were so impressed with the quality of the flat and the building that they decide to come back to Brixton. The area has improved considerably since they left, and now they are happy to be back.

One of the ground floor families, has a disabled child in a wheelchair, and had to endure many years of living in a second floor flat of a building without a lift. They had to carry the child up and down every day. Now they feel so lucky to have a spacious flat on the ground floor with wide doors and adequate fittings for a wheelchair user.

7. TAS Simulations

The environmental performance of six representative flats will be analysed using TAS simulation software[1]. The TAS model used for these simulations was kindly provided by Pratima Washan[2], who carried out a study on Boatemah Walk and Warwick house in 2005. For this study, the internal heat gains from electric lighting, appliances, cooking and water heating have been calculated for each flat using the BREDEM-12 model[3], while the ventilation rates were taken from air testing results provided by the architects and calculated for every flat taking into account variables like: the house volume, the number of passive vents, the regional wind speed and the dwelling exposure.

The building fabric data input in TAS was based on the architects' specifications and manufacturers' literature whenever specified. Otherwise, values were taken from CIBSE Guide A, Appendix 3.A7: Properties of materials[4]

The flats have been chosen due to their differences in level, floor area and internal area to exposed surface ratio; and are indicated in the 3D model below:

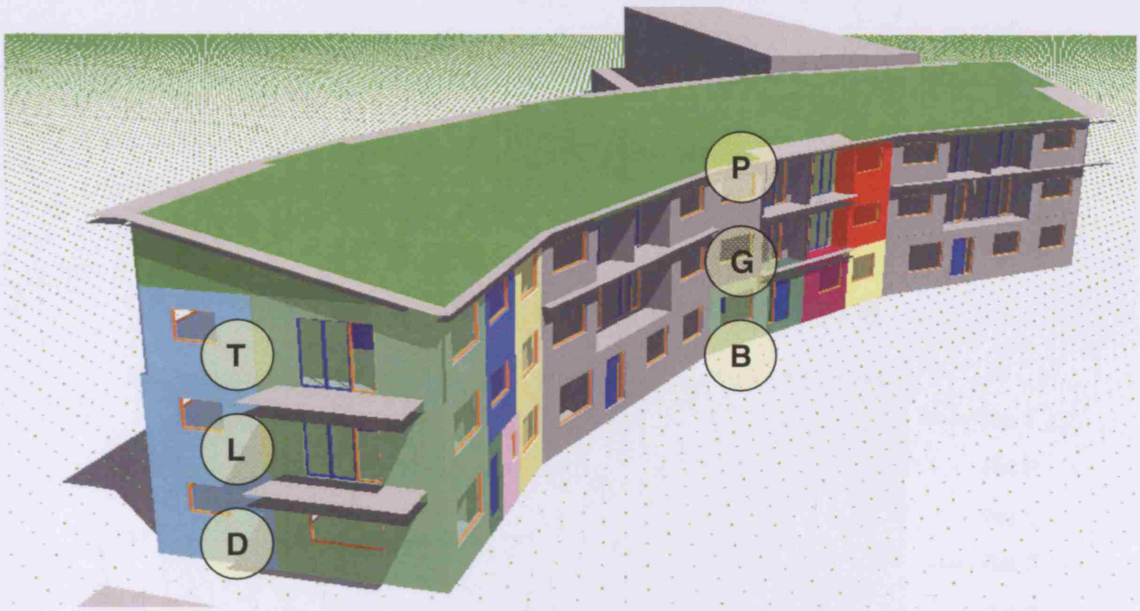


Figure 1- TAS model showing the flats to be analysed

In this section, the following simulations will be carried out:

	Flats	Simulation
Winter performance	T, P, L, G, D & B	Temperature on day 3
	T, P, L, G, D & B	Temperature on day 19
	T	Effects of improving glazing and roof insulation
Summer performance	T, P, L, G, D & B	Temperature on day 3
	T, P, L, G, D & B	Temperature on day 19
	T	Overheating hours above 28°C
	T	Effects of overhangs on solar gains
Overall	T	Annual heating load

7.1. Winter performance- six representative flats

To analyse the winter performance of these flats, two different simulations were performed using the weather file Kew '66, which had particularly cold winter days. Both simulations show the thermal performance of the living rooms, which are all south oriented.

The heating schedule is set to be from 7 to 9am and from 4 to 11pm on weekdays and from 7am to 11pm on weekends to 21°C. Day 3 and day 19 are both weekdays. The windows would be closed at all times, relying solely on trickle vents to provide the necessary air changes.

The first simulation was performed in an average winter day (day 3, 3rd of January), when external temperatures are above 0°C at all times.

- The temperatures inside the flats vary between 16 and 21°C, reaching 21°C during the heating hours, and 16°C in the early morning hours just before the heating starts. The heating schedule seems to be sufficient in length and temperature to keep the comfort levels of working people that leave the flats from 9am to 5pm approximately.
- All flats have a similar performance except flat B (3 bed mid-terrace ground floor flat), which outperforms the rest of the flats, loosing the heat slower during the morning hours.

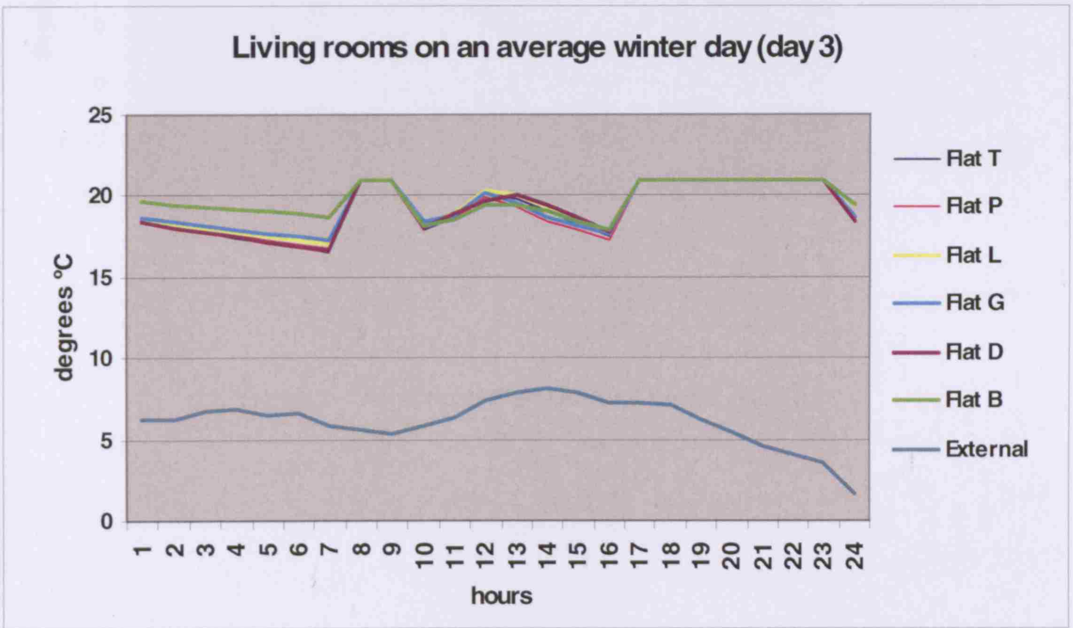


Figure 2- Living rooms temperature profile on day 3

The second simulation was performed in the coldest winter day (day 19, 19th of January), when external temperatures are below 0°C at all times, reaching a minimum temperature of -6°C during the early morning hours.

- The temperatures inside the flats vary between 12 and 21°C, reaching 21°C during the heating hours, and 12°C in the early morning hours just before the heating starts.
- For unusually colder days like day 19, the heating would need to be set higher or longer to avoid temperature dropping below 15°C approximately, depending on personal thermal comfort preferences.
- Flat B (3 bed mid-terrace ground floor flat) outperforms the rest of the flats again, loosing the heat slower.

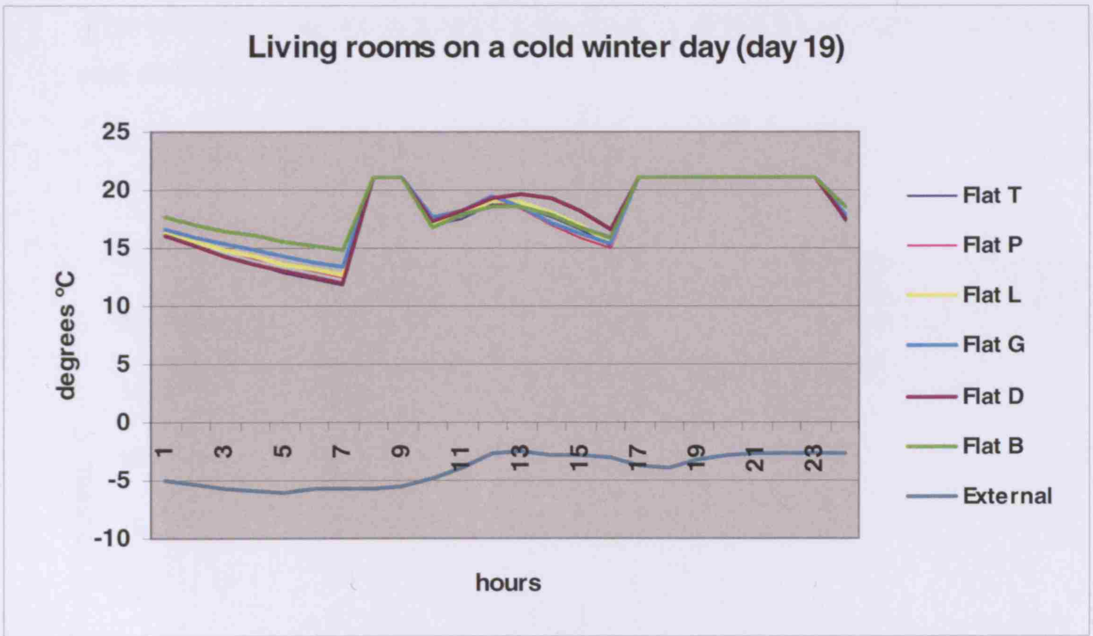


Figure 3- Living rooms temperature profile on day 19

7.2. Winter performance- simulated options

Flat T (2 bed, second floor end flat) has an average performance compared to the other flats and has been chosen to simulate some options aiming to improve the winter performance. The impact of improving roof insulation from 300 to 500mm and replacing the argon filled, Low- E double-glazed windows; by argon filled triple- glazed windows have been simulated separately and are presented in Figure 4.

- Improving the Warmcel roof insulation from 300 to 500mm has a marginal effect, rising the indoor temperature by 0.3°C at most. As a result of this addition, the roof U-value increased from 0.138 to 0.083 W/m^{2}K.
- The effect of replacing the double glazed windows by triple glazing is more noticeable, increasing the indoor temperature by 1.2°C on the early morning hours. The windows U-value of increased from 2.257 to 1.136 W/m^{2}K.
- The small thermal improvement is not likely to justify the change, in terms of cost and embodied energy.

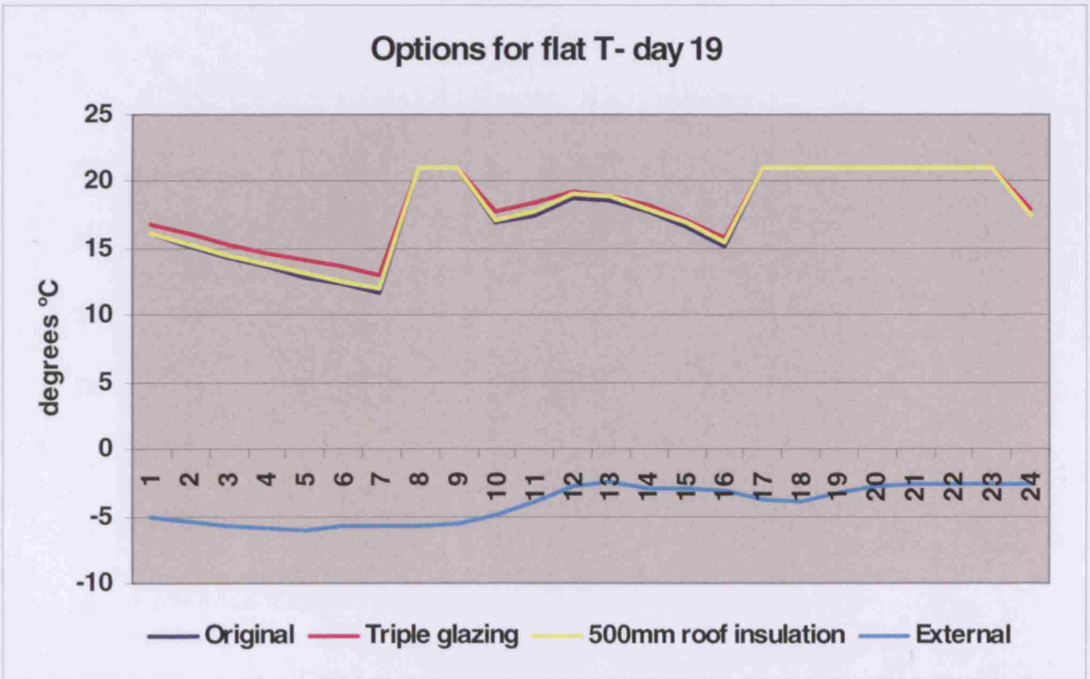


Figure 4- Living rooms temperature profile on day 19, with different options

7.3. Summer performance- six representative flats

To analyse the summer performance of these flats, two different simulations were performed using the weather file Kew '75 '76 '74, which had particularly warm summer days. Both simulations show the thermal performance of the living rooms, which are all south oriented. The flats do not have any means of cooling other than the ones provided by the passive stack ventilation "Passivent" from kitchens and bathrooms and the window aperture schedule.

The window aperture schedule is set to start opening windows when the internal dry bulb temperature reaches 22°C, and to open them completely at 24°C.

The first simulation was performed in an average summer day (day 167), with external temperatures varying between 14 and 26°C.

- All flats have a pleasant temperature varying from 22 to 26°C.
- Flat B gets 1°C warmer than the rest during the peak of the day. This flat tends to conserve heat longer than the others, which can also be seen during winter months.

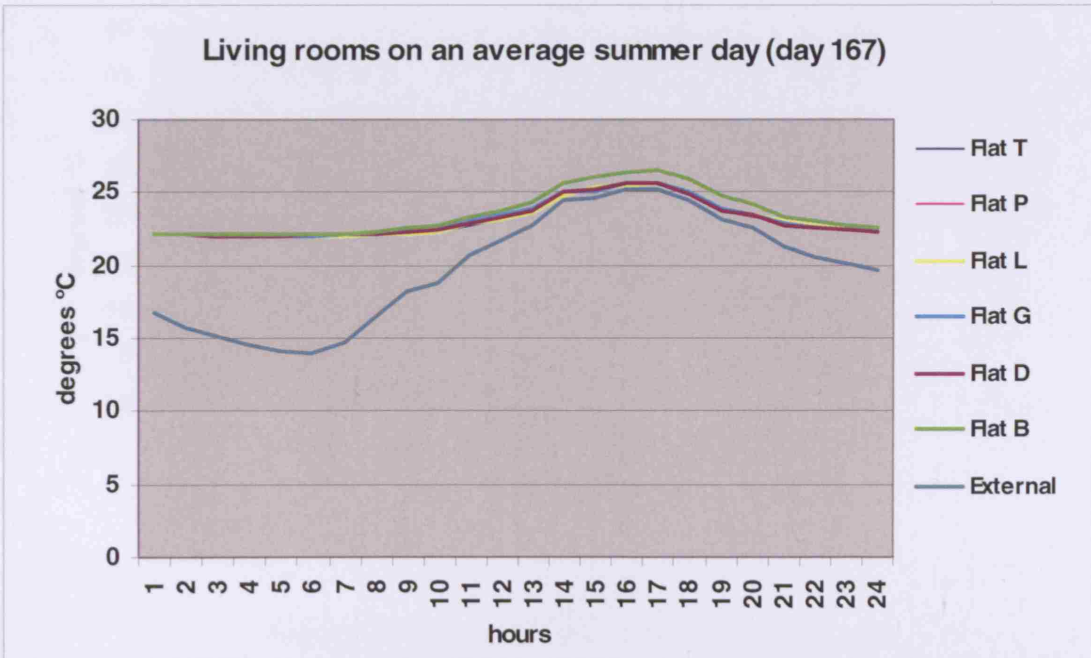


Figure 5- Living rooms temperature profile on day 167

The second simulation was performed on a hot summer day (day 185) with external temperatures varying between 19 and 34°C.

- All flats have an internal temperature variation from 22 to 34°C, reaching the highest temperature during the peak of the day, from 1 to 5pm. This condition could become quite uncomfortable for the occupants during these hours and some have to rely on fans to create air movement and keep cooler, as confirmed during site visits.
- All flats have a very similar thermal behavior, which follows closely the outside temperature. Since there is no thermal mass absorb the heat, the day temperatures follows the same curve inside and outside the flats.
- During the night the internal temperature stays at a comfortable temperature of around 22°C, with the windows closed or slightly opened (due to the window opening schedule)

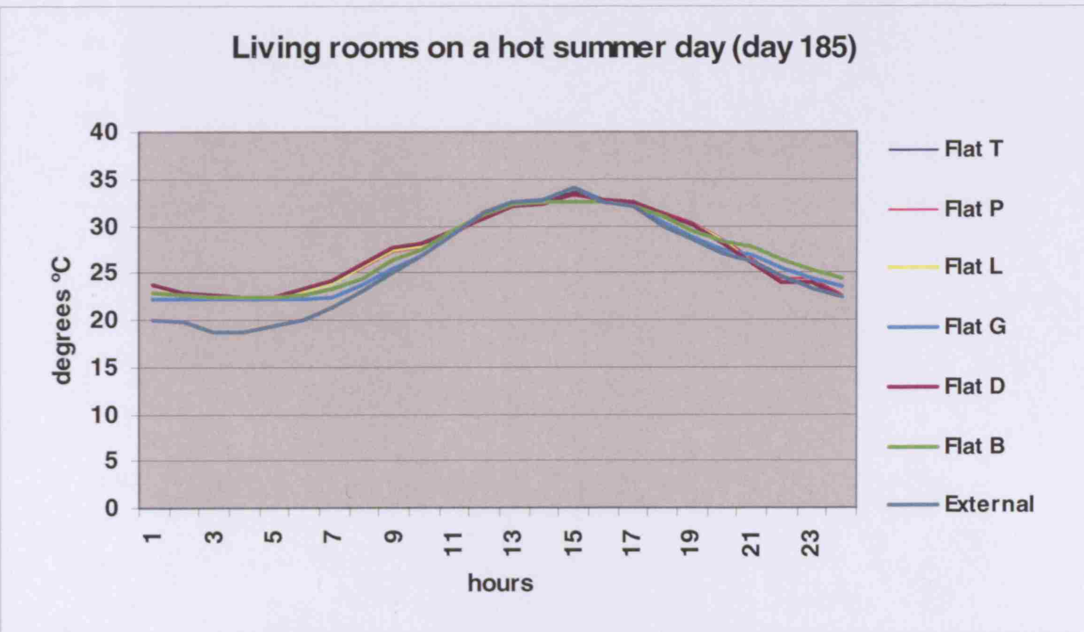


Figure 6- Living rooms temperature profile on day 185

The temperatures rising so high is not a frequent occurrence, however, the effects of global warming are likely to bring longer and hotter summers in the future.

7.4. Summer results- simulated options

Aiming to improve the summer performance, the effect of a horizontal overhang on the south facing windows of flat T has been simulated. Two sizes of overhang have been tested: 0.5m and 1m. In terms of temperature, the effect is negligible, as the open windows allow outdoor temperatures inside the building. (Figure 7)

However, there is a clear effect on solar gains, which increase in proportion with the size of the overhang. (Figure 8)

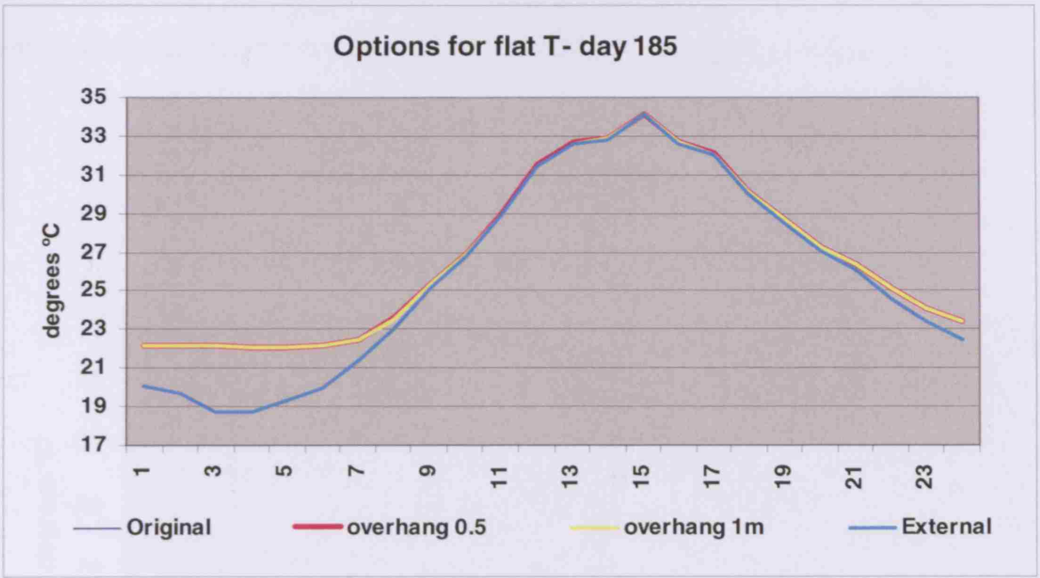


Figure 7- Living rooms temperature profile on day 185

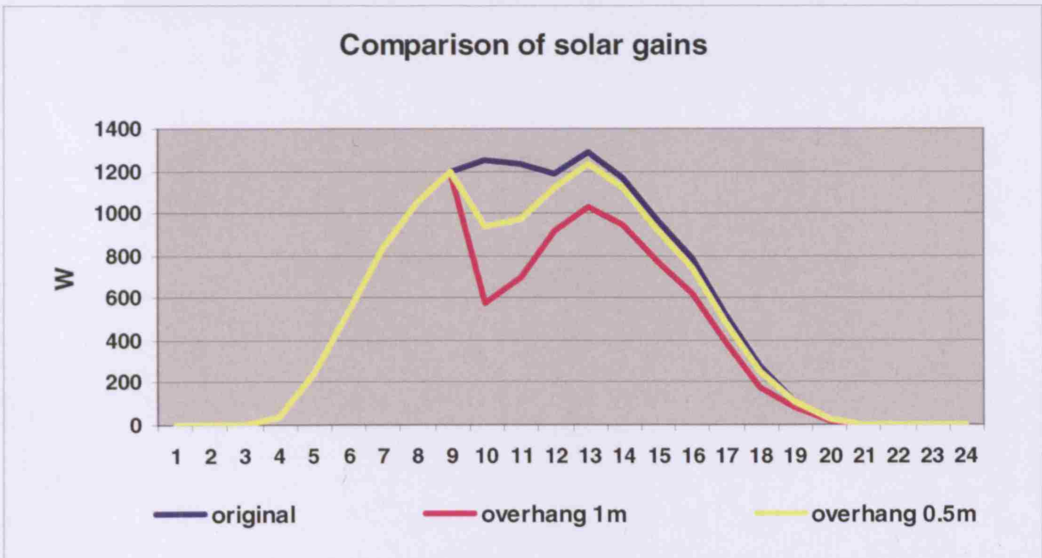


Figure 8- Solar gains comparison on day 185

7.5. Overheating hours

Boatemah Walk is a lightweight building, which is vulnerable to hot temperature, and tends to overheat. In order to find out how often the temperature rises above 28°C (considered for some the upper limit for comfort levels), we have analysed the daily temperature profile from day 120 to day 250 (30th of April to 7th of September) using the weather file Kew '75 '76 '74.

Figure 9 shows the indoor temperature plotted in red, and the 28°C line in blue. The overheating days are mainly concentrated between days 175 to 200. A total of 150 hours distributed in 22 days, have an internal temperature of 28°C or higher.

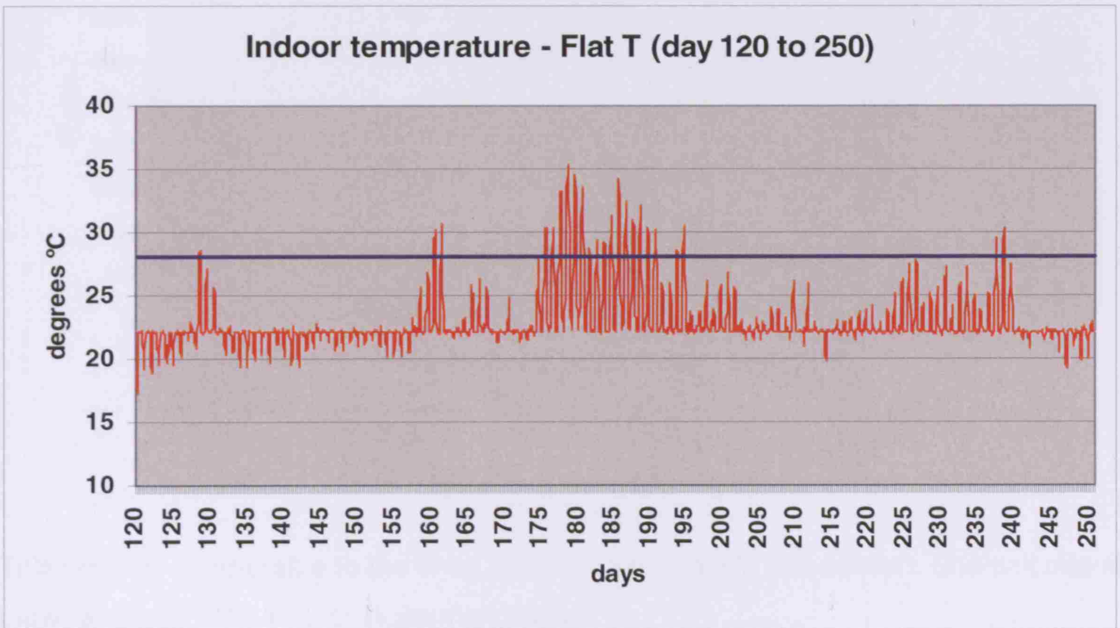


Figure 9- Indoor temperature from day 120 to 250

7.6. Annual heating load

In order to find out the annual heating load, simulations were run for every day of the year using the weather file Kew '75 '76 '74. The figure below shows the annual results, and the sum of the heating loads is as follows:

- Annual heating load for flat T: 2204 kWh/yr
- Annual heating load for flat T per m2: 28.5 kWh

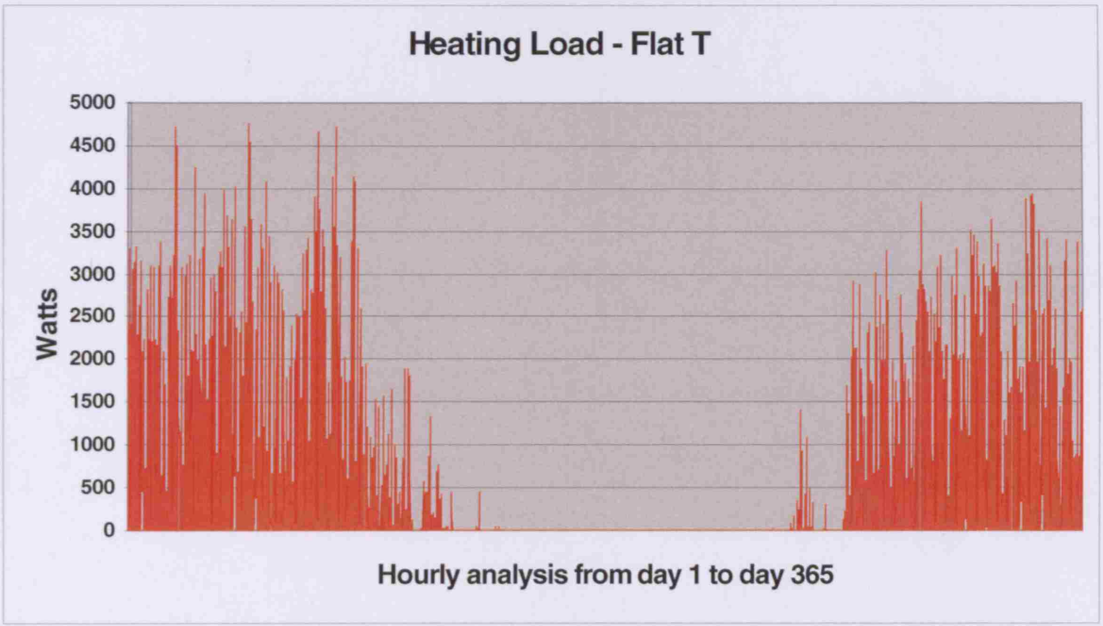


Figure 10- Heating Load Flat T

This result is comparable to the ones in Pratima Washan's dissertation. She calculated between 28-37 kWh/m2 for Boatemah Walk.

Katharine Scott simulated a typical first floor 1-bed flat and calculated an annual heating load of 1120kWh/yr, almost half of what was achieved for flat T (second floor 2 bed) in this simulation. This result is also comparable in proportion to flat size.

[1] TAS simulation software is used to analysed the environmental performance of buildings, more information can be found at: www. edsl.net

[2] Pratima Washan "Refurbish or Redevelop? A sustainability comparison for social housing in Brixton" MSc Dissertation, University of London, 2005

[3] B R Anderson, P F Chapman, N G Cutland, C M Dickson and L D Shorrock (1996) BREDEM-12 Model Description. Building Research Establishment Laboratory Report, UK (Referenced in Pratima Washan dissertation[2])

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8. Discussion of the results

8.1. Reducing carbon emissions from buildings

Energy use from buildings represents a considerable share of the UK energy consumption as a whole and the contribution from renewable sources is still very low in comparison to countries like Germany, Sweden and Denmark for example.
Aiming to reduce the carbon emissions from building operations, the UK government is encouraging the micro generation technologies through initiatives like the "Low carbon building program" which replaced the "Clear Skies" program. In addition, up to £420 million will be invested in improving the housing conditions of London's councils, as part of a broader "London Housing Strategy" initiative. (See 1.2)
Programs like this will help break the affordability barriers and ensure more on- site renewable energy generation gets installed.
The borough of Lambeth has taken action to improve the energy efficiency of their housing stock, and Angell Town regeneration is an example of this. Boatemah Walk is a demonstration project for the use of renewables and efficient use of energy and water. Predictions for the energy and water saved were made before Boatemah Walk was occupied, and previous studies carried out by Pratima Washan and Katharine Scott, as mentioned before, gave an insight to this projected building performance.

8.2. Brief review of previous studies

As part of her dissertation, Katharine Scott calculated the carbon and economic payback times for the photovoltaic roof, considering a lifetime of 30 years. In terms of carbon payback, she found that the building would save 5,624 kg CO_2 to the environment every year, thus 168 tonnes of CO_2 through its lifetime. The roof's embodied carbon was calculated to be 33,893 kg CO_2, therefore the carbon payback time is 6.03 years. After six years of use, the building will start saving CO_2 to the environment through the use of the photovoltaic roof production.
In terms of economic payback, it was found to be 76.1 years when grants were included, and 176.6 years excluding grants. In both cases, the economic payback remains longer than the lifetime of the system.
Pratima Washan compared the new built Boatemah Walk and the refurbished Warwick House building in terms of life-cycle energy use and carbon emissions. The new built Boatemah Walk has more embodied energy, even though it is timber-framed; however it outperforms marginally the refurbished Warwick House in terms of operational energy

requirements. The refurbishment option was found to have much reduced environmental impact at a reduced capital investment. Refurbishment is therefore, the preferred option, as indicated in Pratima's study.

8.3. Performance of the building today

Boatemah Walk has been built with to require low energy consumption, outperforming the requirements of current building regulations. The building also benefits from renewable energy generation on-site from photovoltaics, and a rainwater recycling system. It has been occupied for a year, achieving a 90% satisfaction from the residents.
The monitoring and observations carried out during the year indicate the following:

Photovoltaics

The photovoltaic system was designed to supply the demand of the tenants directly, selling any surplus to the electricity company, in this case EDF. In order to achieve this, export meters had to be installed and this had not happened. The surplus electricity is being exported as it is produced; however, Lambeth is not getting any payment for it. Monitoring of the building in use has proved that the electricity production of the photovoltaic roof is comparable to the projected one; and the production is either used on site or exported, thus the carbon payback time calculated in Katharine Scott's report is achievable.

Due to the lack of export meters during the last year, the surplus electricity exported to the National Grid could not be quantified and paid for; hence the economic payback time would have to be revised.

In addition, the lack of export meters did not allow proper monitoring. The share of electricity produced by the roof that ground floor tenants have used is uncertain; therefore the actual annual electricity demand cannot be determined. However, the half-year monitoring of seven households, in terms of electricity consumed from mains, allows an annual projection to be assumed (see figure 15, chapter 5.2) and compared with the projected annual demand of 3,000-kWh/ household calculated in Katharine Scott's report. Considering that ground floor households' consumption from mains is already close to 3,000 kWh, it is very likely that the total result, including the electricity used from photovoltaics will reach a higher amount.

Rainwater recycling

The rainwater recycling system aims to maximise the use of rainwater for toilet flushing, reducing the dependency from the mains water. The header cistern was inspected by

Cath Hassell in late July, who found chalky deposits, a indication of mains water being used in a regular basis. There was also evidence of rainwater being used at some point, but the lack of a biofilm suggested that it has not been much. Speculations about the performance of the pump were made and also recommendations for the whole system to be checked.
The contractors were on site in early August to test the system and found that it was working correctly. They attributed the extensive use of mains water to the recent lack of rainfall. How much rainfall has been used is something unknown, because an essential element to allow precise monitoring was omitted: a meter for rainwater entering the header cistern. Both reports can be found in the appendix C.
The availability of rainfall, which is a key factor to fulfil the aims of the system successfully, is something unpredictable. The last months have been particularly dry; it is therefore likely that very small amounts of water have been collected. A calculation of the potential rainfall collected by the Boatemah Walk's 650m^2 roof area was done (see 5.5), using the Met offices' rainfall records of the past 12 months for the south east of England. This shows that rainfall has been enough to supply the system entirely, but then again, this record corresponds to a wide area and the local rainfall is something uncertain.

Building fabric
The building fabric has been successful in keeping thermal comfort with low energy consumption outperforming the requirements of current building regulations. All elements have been designed to high specification (see 4.3), considering both low embodied energy of materials and heat conservation.
As mentioned in section 5.1.1, Boatemah Walk's households generally consume below the country's lowest values. The UK averages annual domestic gas consumption per households measured in 2003 fluctuates between 18,000 and 22,000 kWh (see 1.2). In comparison, the annual average gas consumption for Boatemah Walk's monitored flats is 13,255 kWh.
It is clear that space heating requirements are considerably low; which confirms the contribution of Boatemah Walk's energy efficient building fabric to energy conservation. However, in summer the lightweight building with opened windows tends to overheat and replicate the external temperatures. Many tenants have to resort to switching on electric fans to keep cool, which goes against the aims of a naturally ventilated building. Having said that, fan use takes place during the peak of the day, which is when electricity is being produced by photovoltaics. Consequently, there would not be carbon emissions produced as a result of fan use.

8.4. Tenants evaluation of the building

For all tenants interviewed, it was the first time they live in a 'green' building. In most cases they felt very fortunate to be offered council accommodation of such high quality. The economical advantages of reducing their energy consumption is known to them, but the concepts of reducing their ecological footprint and save carbon emissions to the atmosphere were not as known. Living in a 'green' building has had a positive influence on them, making them more aware of the environment. Most tenants have started to follow with interest the news concerning the environment since they moved into Boatemah Walk, and are very keen to know more about the technologies installed in the building such as the photovoltaic panels and rainwater recycling system. Moreover, the improved dwellings and enhanced communal space has raised their quality of life, giving them a more positive view of life and a sense of pride about their environment.

The tenants' evaluation of the building is very positive in terms of thermal comfort, daylight quality, reduced pollution levels and the technologies installed.

In terms of noise during day and night time the evaluation was not as positive as some tenants are disturbed by the noise from neighbours, people on the streets and in less proportion, car traffic. The building has been acoustically insulated, however, if the windows are open there is no barrier for the noise to enter. Having said that, the noise disturbance is a problem of the neighbourhood, rather than of the building itself.

Some tenants also mentioned that their flats get hot on some summer days. They were not too troubled with this because is not a frequent occurrence and they tend to mitigate the effects of the heat switching on fans on the peak of the day.

Sixteen questions were asked to evaluate different aspects of the building. Weighing the tenant's answers in a scale of 0 to 100, 0 for very poor and 100 for excellent performance, the average satisfaction with the building scored an 89. The chart showing the summary of all answers can be found in Appendix D.

8.5. The impact of energy consuming behaviour

People's attitudes towards energy conservation are a key element for a successful building performance. The willingness to save energy through daily habits is different for every individual depending on their values and beliefs, levels of education and environmental concern. (See section 2.4) However, the human factor is unpredictable, and even individuals with higher environmental concern do not control their energy consumption all the time. The tenants were explained about the features of the building they were to occupy and distributed a leaflet describing them in detail. Despite this, some tenants wrongly believed that moving into a low energy building would allow them to consume more and pay a cheaper rate, which goes against the principles of low energy design. The above-average consumption of the first months gives an indication of this. There seems to be a change in attitude since then, however, there is a need for real commitment to reduce the environmental impact of their lifestyles, which will also result in reduced bills.

Boatemah Walk has a varied mix of tenants. The survey shows that preferences and daily choices are divided. The results broadly indicate no special commitment to save energy and water in some individuals, but also enthusiasm and willingness to change in others. Nineteen questions were asked to evaluate daily habits that have an impact in energy consumption. All answers were allocated a score depending on the level of environmental effect the action has, 0 for negative and 100 for positive environmental impact. The chart showing the summary of all answers can be found in Appendix D.

8.6. Simulation results

Six representative flats were simulated using TAS software (see section 7), and the results show the following:

For typical winter days with temperatures between 2 and 9°C, the heating regime used (set at 21°C from 7 to 9am and from 4 to 11pm) is sufficient to keep the internal comfort levels. On a cold winter day with temperatures fluctuating around –2 and -6°C, which is not frequent, internal temperatures drop below the 15°C (considered below comfort levels) hence a long heating regime needs to be considered. The winter performance has been simulated using the weather file Kew '66, which had a particularly cold winter.

When simulating the effects of improving the roof insulation and replacing the double glazed windows by triple glazed, the effects are marginal, and are not likely to justify the investment in terms of cost and embodied energy. This is an indication that the level of insulation of the building has already achieved an optimum.

The strategy in summer is to have natural ventilation with a window aperture schedule set to start opening windows when external temperatures reach 22°C and open them completely at 24°C. The summer performance has been simulated using the weather file Kew '75 '76 '74, which had a particularly warm summer.

On an average summer day with temperatures fluctuation between 14 and 25°C, the flats maintain a pleasant temperature without the need for any additional cooling, however, in a particularly hot summer day (like day 185 of the weather file mentioned above) with temperatures reaching 34°C outdoors, the internal temperature follows closely the external. The windows are scheduled to be opened completely for ventilation, but the lack of thermal mass in Boatemah Walk does not allow for heat absorption and it gets as hot inside as outside.

The effect of an overhang placed above the south-facing windows was simulated. It was found to reduce solar gain inside the flats, but had no effect in reducing the temperature. (which is dependant on whether the windows are opened or closed)

The summer simulation confirmed what happens in real life. The tenants indicated during their interviews the need to switch on electric fans on the hottest days.

To find out the frequency of this event a simulation was carried out to find how many hours the internal temperature gets above 28°C. It was found that, for this weather file there were a total of 150 hours distributed in 22 days when internal temperatures reach above 28°C, which is considered above most people's comfort levels.

A final simulation was carried out on a representative flat (flat T: second floor 2 bed flat) to find the annual heating load. This gave a result of 2204 kWh or 28.5 kWh/m^2. This amount is closely comparable to the 28-37kWh/m^2 calculated by Pratima Washan, and in proportion with Katharine Scott simulation of a smaller flat, which gave a result of 1120kWh annual load.

However, the projected annual gas consumption taken from last year monitoring indicates a much higher amount of 14,758 kWh for the simulated flat, and 13,255 kWh as an average of all simulated flats; 6.6 times the amount given by simulations.

It should be considered, that personal preference in temperatures could increase the consumption considerably. Moreover, the fact that simulations are the result of many assumptions could compromise the accuracy of the results.

9. Conclusions

Low energy developments are increasingly being built in the wake of climate change concern and regulations enforcing new energy efficiency standards. It is important that demonstration projects like this provide feedback to prove the efficiency of the systems to encourage the investment on new technologies and similar developments.

Performance in use of Boatemah Walk building has proved successful in some aspects and less successful in others.

The photovoltaic panels have been producing electricity according to the projected figures, and ground floor tenants have been benefiting from it as planned. The surplus production has been exported to the Grid, however, due to the lack of export meters it has not possible to quantify the amount the electricity company needed to pay Lambeth. Likewise, it is not possible to know the amount of electricity consumed on site.

After discovering this omission earlier this year, negotiations between them are taking place to have export meters installed. The projected carbon payback time of 6.03 years, calculated by Katharine Scott is still realistic, but the economic payback would need to be revised.

Regarding the rainwater recycling system, there is still uncertainty about how efficient it has been this far. After discovering that the cistern has been filled with mains water in a regular basis, Cath Hassell recommended a complete check of the system. The contractors found it was working correctly and attributed the fact to the lack of rainfall. Rainfall calculations for the south east of England suggest that it has been enough to supply the projected demand. There is evidence that suggests some minimal use, however, the lack of a meter for rainwater use make impossible to quantify the amount of rainwater used.

It is crucial that a demonstration project like Boatemah Walk building considers all mechanisms necessary to monitor its efficiency. Boatemah Walk building was designed and built to very high standards, but lacks of some key elements to enable its monitoring, which has proved an obstacle for the purpose of this report.

On the positive side, the building fabric has been designed to high specification in terms of heat conservation and low embodied energy. It achieves a monitored annual consumption of approximately 13,000 kWh per household, below the national averages of 18,000-22,000 kWh, but much above the value simulated with TAS software: 2204 kWh. The assumptions made when using TAS, together with the possible high consumption by the tenants could be the reasons for this disparity.

In hot summer days the lightweight building is inevitably vulnerable to the outside temperatures and the tenants resort on electric fans to keep cool. This is not a frequent occurrence, however the effects of climate change are very likely to increase the length and temperatures in the future. Fortunately, this electric load during the peak of summer day is most likely to be supplied by photovoltaic production, which would mean that no carbon emissions are produced as a result of fan use.

The survey indicates that the tenants' energy consuming behavior has a definitive impact on the overall consumption. Boatemah Walk tenants are families and individuals with different backgrounds and values, thus different consuming habits. Some have not shown real commitment, and others are enthusiastic to acquire a low energy lifestyle. This determination reflects in their bills, and in the overall performance of the building.

One of the most successful aspects of this development is probably the effect it is having in the community. The tenants are highly satisfied with building and the ones who used to live in Angell Town when it was an anonymous and unsafe series of concrete buildings have experienced a very positive change in their life quality and a sense of pride about their community.

On balance, there are many positive aspects to highlight from this demonstration project, and also lessons to learn. For the UK to achieve its carbon reduction targets, it is important to have the contribution of more low energy housing developments like Boatemah Walk. It is crucial to ensure that the residents are fully aware of the importance of reducing their consumption as this has a comparable or greater influence in the total reduction than the technologies installed. There is a potential for things to go wrong, even with technologies that have been tried and tested for years. For this reason it is necessary to provide regular checking and maintenance to make sure the systems are working correctly, and monitor its contributions. A successful low energy building not only provides reductions in carbon emissions and costs, it also enhances the quality of life of its residents and the wider community.

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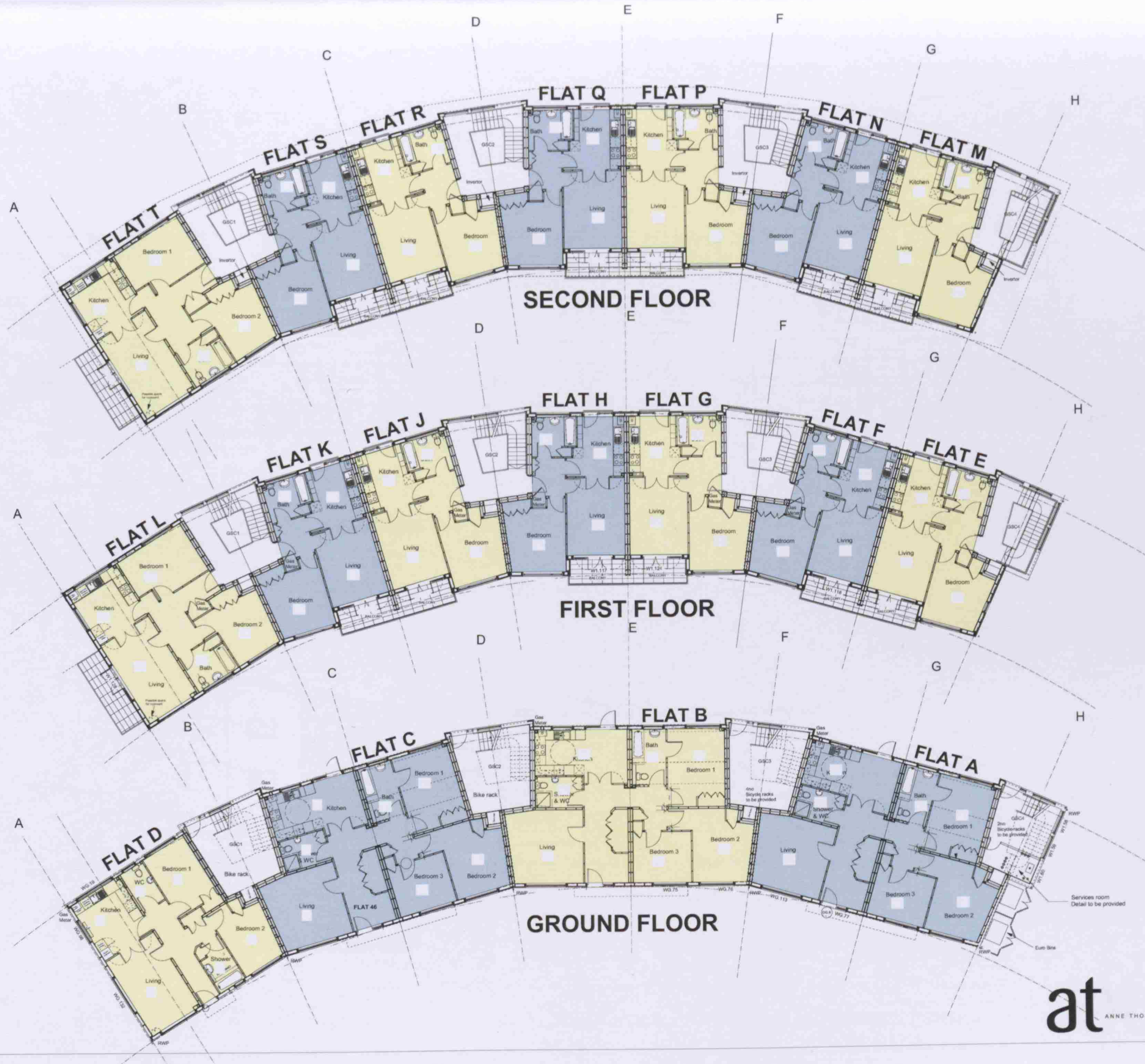
Appendix A- Architects' Drawings

Architects' drawings include floor plans, roof plan, elevations and typical section kindly provided by Anne Thorne Architects Partnership.

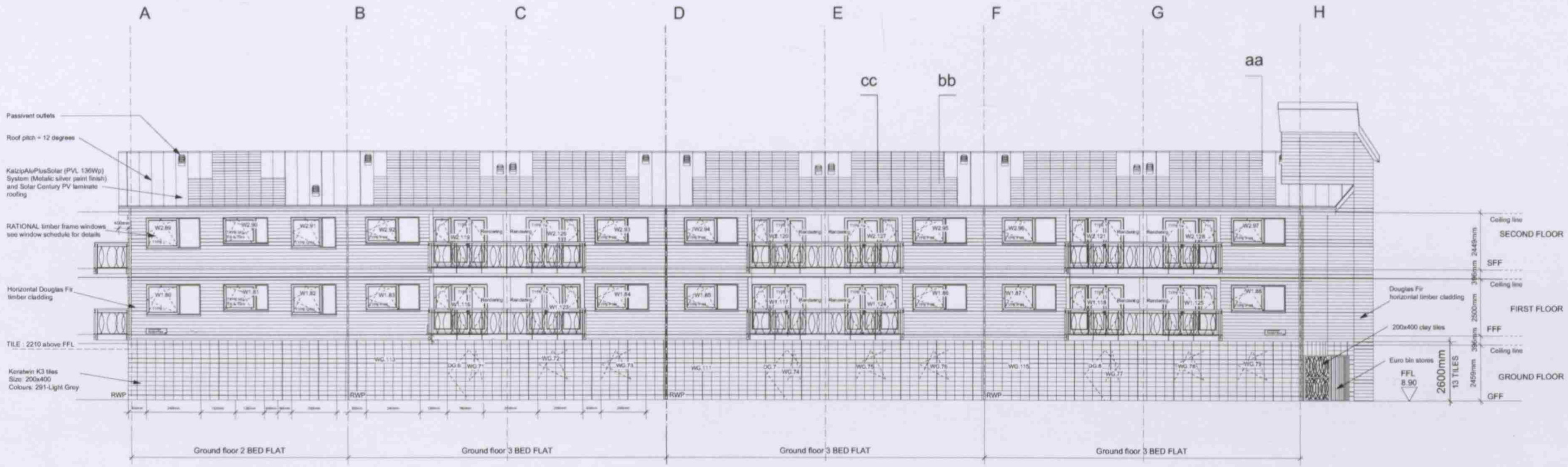
The floor plans have been customised for the purpose this report. Every flat has been assigned a letter according to the monitoring analysis carried out in Chapter 5.



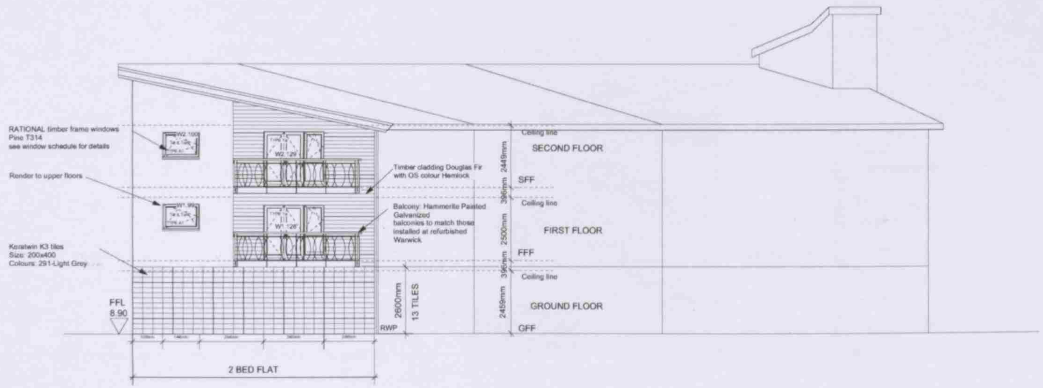
No	Date	Description of Revisions

Client: London Borough of Lambeth			
Site: Warwick New Build			
Drawing title: Ground, First and Second Floor Plans			
Scale: 1:100	A1	Date: April 2004	
Dwg No: 178/F/100		Revn: H	
All dimensions to be checked on site. Do not scale off this drawing			

at ANNE THORNE ARCHITECTS PARTNERSHIP



SOUTH ELEVATION



WEST ELEVATION

Note: Dimension to the underside of cill

No	Date	Description of Revisions
G	[illegible]	- canopy omitted - Roof & bins updated - Street name added
F	[illegible]	- Window WG.98, W1.99 & W2.100 Tilt & Turn
E	[illegible]	- Storey height amended - Roof system amended - Tiles Colour: 291-Light Grey - Balcony updated - render amended
D	[illegible]	- 2 bed flat entrance door (no.DG.5) Type D - Windows amended SEE windows and door schedules 178/F/900B, 178/F/930B & 178/F/931B
C	[illegible]	- Ground floor bathroom & WC window height amended (WG.69 size amended) - RWP position amended - Kalzip PV laminate roof drawn - Window type MQ post removed
B	[illegible]	- Window WG.69 amended
A	[illegible]	- 2 bed flat 1st & 2nd floors bathroom/WC window amended to type MQ - 2 bed flat ground flr Front door amended - 1 bed flat kitchen balcony door amended. - Windows Type to windows W1.84, W1.86, W2.93 & W2.95 amended - Windows and doors position amended - Door DG.6 side panel omitted

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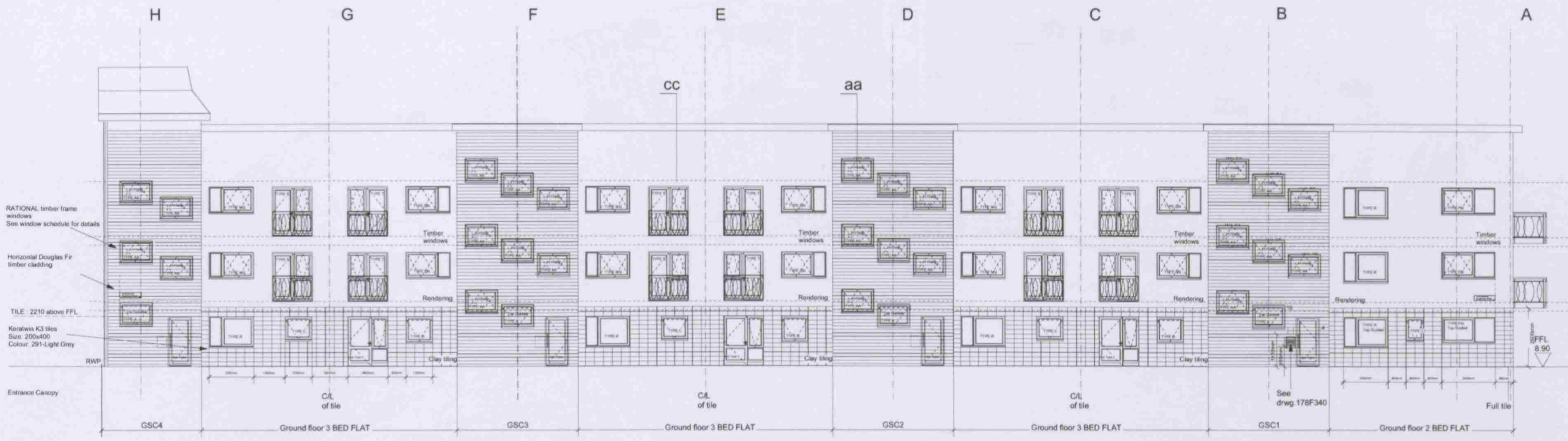
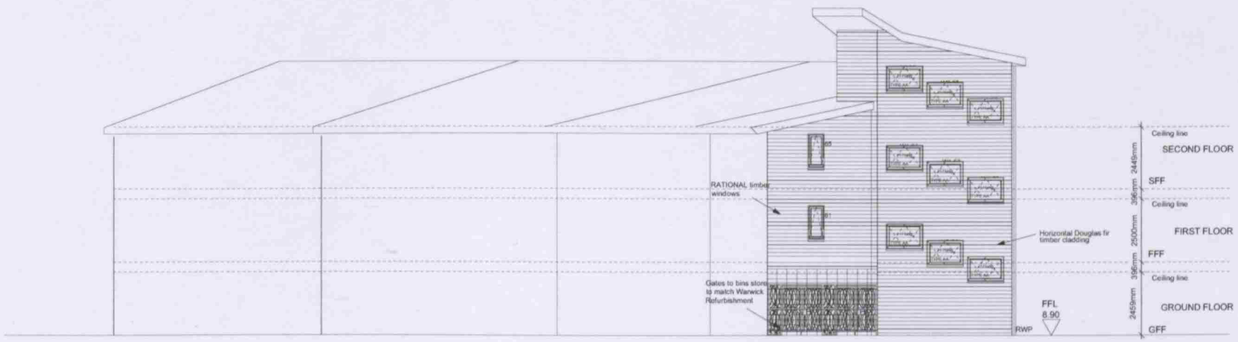
Client	London Borough of Lambeth
Site	Warwick House New Build
Drawing title	South & West Elevations
Scale	1:100 — A1 — Date: April 2004
Dwg No	178 F 300 — Revn: G

All dimensions to be checked on site
Do not scale off this drawing

at
ANNE THORNE ARCHITECTS PARTNERSHIP



NORTH ELEVATION



EAST ELEVATION

Note: Dimension to the underside of cill

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G	[illegible]	- Canopy omitted - Bin store updated - Street Name added
F	09/08/04	- Window Type R (windows W1.37 & W2.56) Handle amended to H-window - Window Type PN (windows W1.38 & W2.57) amended to H-window - Door type C side window amended to Top Guided
E	[illegible]	- Opening lights amended to H windows, - storey heights amended - render amended
E	15/07/04	- Tile colour amended - Floor level amended to Global timber frame drawing
D	2/07/04	opening lights amended, stair windows changed to H pattern
C	[illegible]	-Ground floor window height amended (Windows WG.3, WG8, WG.13 & WG18 amended) - Staircase window position amended - Tower stair windows WG.1, W1.20 & W2.39 amended - Window type MQ & QN post removed
B	[illegible]	- Window WG.2, WG.7, WG.12, WG.17, W1.37, W2.56 amended to window type R - window type S added
A	[illegible]	- Window Type T position amended, - Windows and doors position amended

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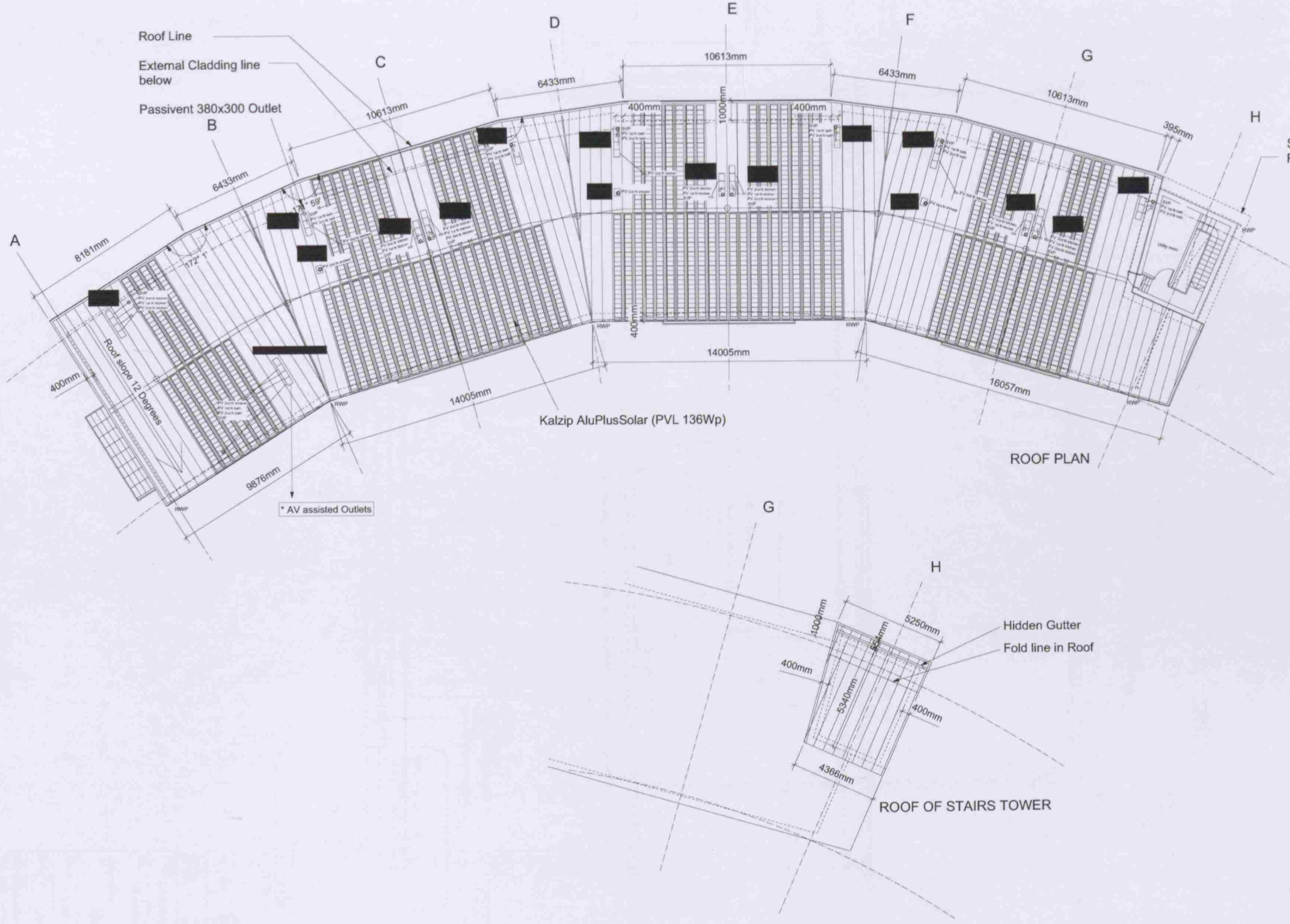
Client	
Site	
Drawing title	
Scale	Date
Dwg No	Revn

All dimensions to be checked on site
Do not scale off this drawing

at ANNE THORNE ARCHITECTS PARTNERSHIP



No	Date	Description of Revisions
B	11/08/1	- Roof Dimensions added - PV outlets rotated - Roof slope arrow - RWP location added
A	12/07/0	Terminals amended - PV amended - Overhang of roof and balconies amended - Roof system amended to correct PVL 136 system (106 units*). SEE Solar Century Design - Tower staircase roof added - Harness moved

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Client	London Borough of Lambeth		
Site	Warwick House New Build		
Drawing title	Roof Plan		
Scale	1:100	A1	Date 14 June 2004
Dwg No	178.F.120	Revn	B

All dimensions to be checked on site

Do not scale off this drawing

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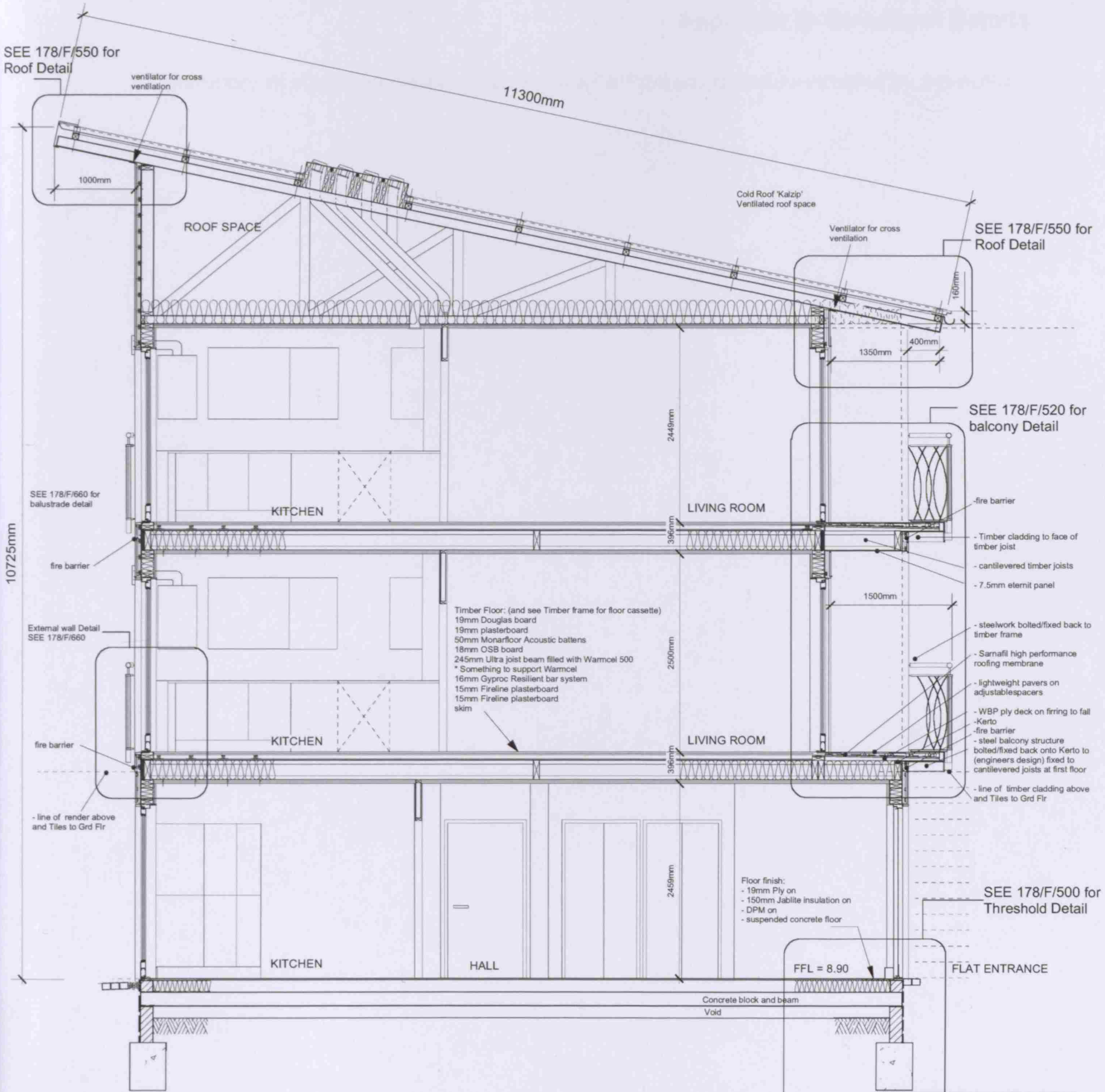

No	Date	Description of Revisions
B	12/05/05	Fire break to external wall
A	27/10/04	2nd Floor ceiling updated 300mm insulation Roof truss Balcony reference 178/F/660

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Client	London Borough of Lambeth
Site	Warwick House New Build
Drawing title	Section CC

Scale	1:50	A3	Date	July 04
Dwg No	178 F 200		Revn	B

All dimensions to be checked on site
Do not scale off this drawing

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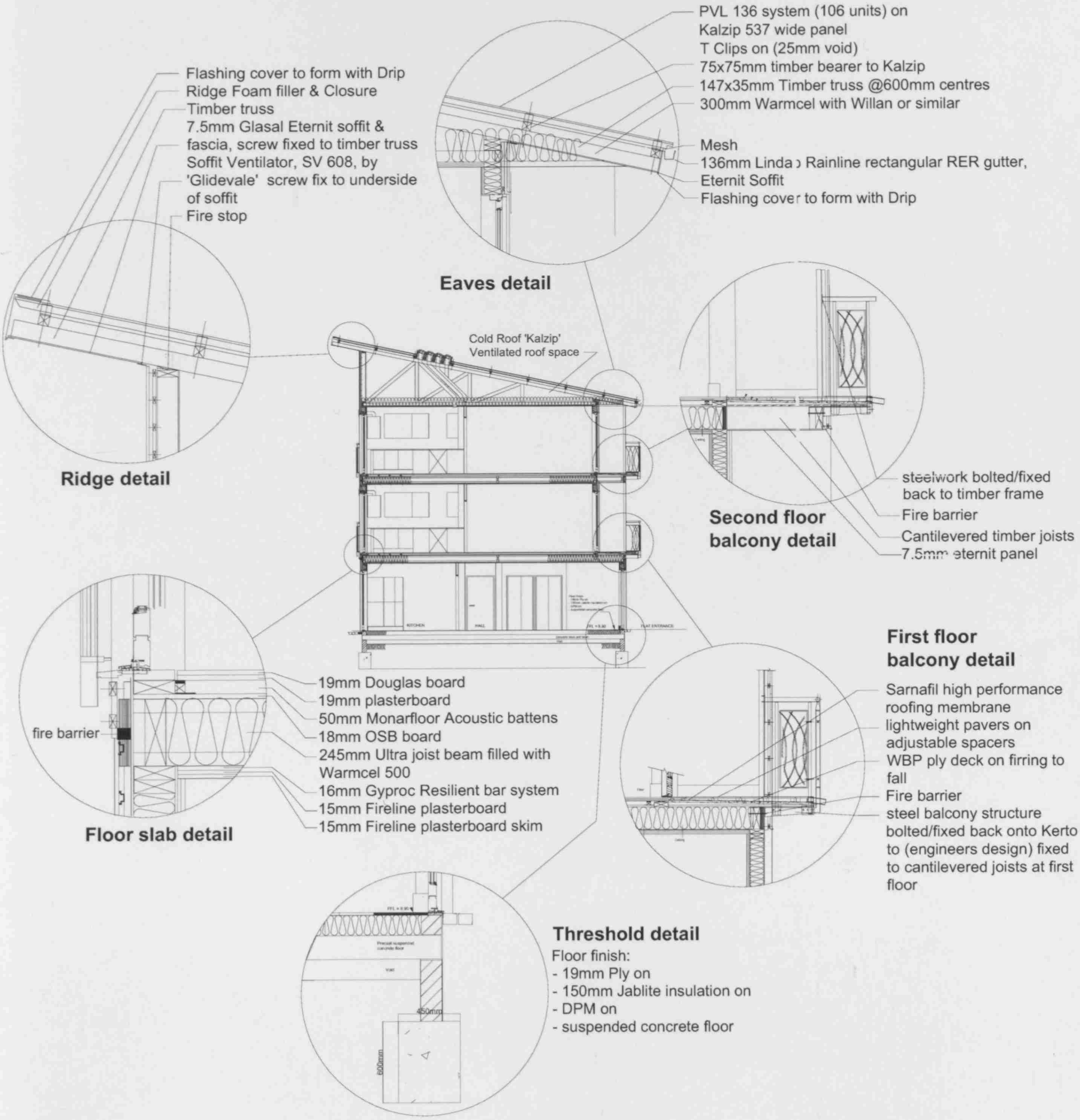
Appendix B- Structural Details

Summary of structural details taken from ATAP drawings and assembled by the author.



PVL 136 system (106 units) on
Kalzip 537 wide panel
T Clips on (25mm void)
75x75mm timber bearer to Kalzip
147x35mm Timber truss @600mm centres
300mm Warmcel with Willan or similar
Mesh
136mm Linda› Rainline rectangular RER gutter,
Eternit Soffit
Flashing cover to form with Drip
Flashing cover to form with Drip
Ridge Foam filler & Closure
Timber truss
7.5mm Glasal Eternit soffit & fascia, screw fixed to timber truss
Soffit Ventilator, SV 608, by 'Glidevale' screw fix to underside of soffit
Fire stop
Eaves detail
Cold Roof 'Kalzip' Ventilated roof space
Ridge detail
steelwork bolted/fixed back to timber frame
Fire barrier
Cantilevered timber joists
7.5mm eternit panel
Second floor balcony detail
First floor balcony detail
Sarnafil high performance roofing membrane
lightweight pavers on adjustable spacers
WBP ply deck on firring to fall
Fire barrier
steel balcony structure bolted/fixed back onto Kerto to (engineers design) fixed to cantilevered joists at first floor
fire barrier
19mm Douglas board
19mm plasterboard
50mm Monarfloor Acoustic battens
18mm OSB board
245mm Ultra joist beam filled with Warmcel 500
16mm Gyproc Resilient bar system
15mm Fireline plasterboard
15mm Fireline plasterboard skim
Floor slab detail
Threshold detail
Floor finish:
- 19mm Ply on
- 150mm Jablite insulation on
- DPM on
- suspended concrete floor
450mm
600mm

Appendix C- Rainwater recycling performance reports

Report produced by Cath Hassell of ech2o environmental consultants

Report produced by Sandwood contractors

Report on the rainwater harvesting system at Boatemah Walk

- I visited Boatemah Walk on July 21st with Lidia Vargas, an MSc student who is monitoring both the PV and RW systems there. The aim was to explain to her how the RWH system worked. I am concerned that they system is not working correctly, as it appears that no rainwater is getting to the header cistern. It is important that they whole system is checked for correct working asap.

Current situation

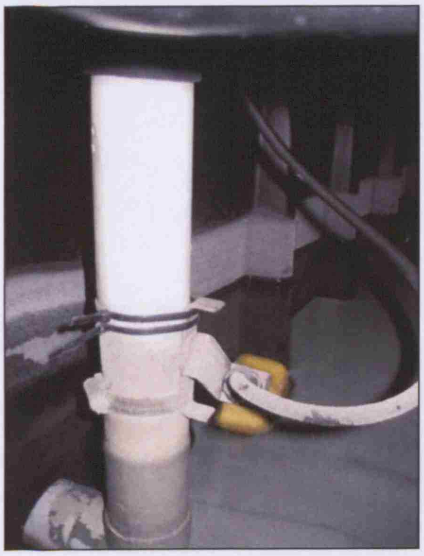
- Looking at the water inside the header cistern, it appears that there has been no rainwater in that tank for many months. I have based this on the chalky deposits on the floor of the tank whereas I would expect to see a thin biofilm if the tank was receiving rainwater regularly.

- I was told verbally by the plumber on site that the system was working fine when first put in and rainwater was being pumped up to the cistern. You can see that from the tide mark in the header cistern that at some point the water level has been higher and this can only have been from rainwater from the storage tank.

- The rainwater float switch is calling for water. If there is water in the underground tank then this will be pumped up to the header cistern. I could not check the water level in the rainwater storage tank as I did not have the tools to access it. It has not rained for several weeks so a lack of rainwater would be expected, but the lack of biofilm in the tank suggests no rainwater is being pumped up there .

- The reading from the meter implies that virtually all the supply to the flats has been from mains back up, (although this is making certain assumptions about the level of WC flushing in the flats.)

- The pump controller is not showing any faults



Possible faults

- The pump control float switch is unable to move freely and is still in the off position despite there being rainwater in the tank
- The pump has fallen over and trapped the pump control float switch
- The chalky deposits are a sign of ingress of ground water into the tank and this has clogged up the floating filter to the pump
- The pump control switch has been wired up incorrectly although I think this is unlikely as if it was the pump probably wouldn't have worked in the first place

Other points

- The mains back up float switch is working correctly. Therefore the tenants can flush their toilets. However no savings are being made from using rainwater instead of mains water
- There is no meter on the rainwater supply to the tank. This means it is impossible to calculate how much rainwater the system has supplied. Originally the drawings showed one meter only but this error was pointed out to Mendick Waring and a new drawing supplied to site.
- The header cistern is not lagged properly, nor is the pipework lagged properly

Cath Hassell
July 24th 06

Report on rainwater harvesting system at Boatemah Walk

Billy Eastman- Sandwood Construction August 8th 06

Myself and James Millen from Sandwood construction visited the above address on the 8th August to investigate the following problems with the rain water harvesting system following the report from Cath Hassell dated July 24th 06 I attended site and made the following points.

The pump was in the upright position supported by the lowering rope supplied (fig 1). The water level was measured and found that there was only 225mm of rain water in the tank obviously due to the recent lack of rainfall (fig 3), this would mean that the pump control flow Switch that is attached to the pump as a safety device to stop the pump running dry would not activate. As a check the switch was manually activated at the pump and the header system and was found to be operating correctly.

fig 1

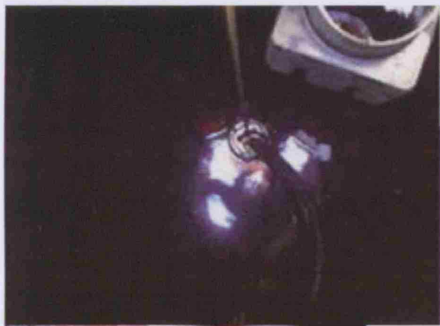


fig 2

fig 3

In the pump controller cupboard the under ground water level indicator was showing only 6% of water (fig 4). If this had been measured more accurately, it would have confirmed that the lack of rain fall in recent months has resulted in the need for the headed tank to use the mains to meet the demands of the tenants.

fig 4

There was no meter shown on the original drawings for the rain water supply only on the mains water supply but now one has been fitted for monitoring purposes (fig 5)

Fig 5

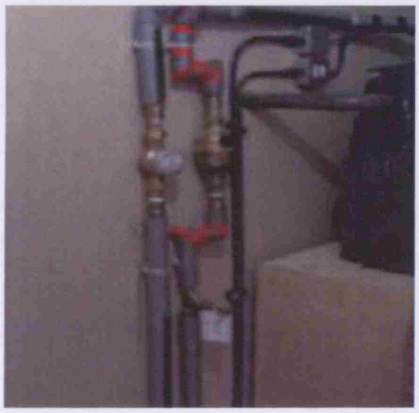


Fig 6

The pipe work and header cistern has now had its lagging reinstated (fig 6), the system has been thoroughly checked over and found to be wired and plumbed correctly, our findings suggest that the lack of rain fall over the recent months is the cause for the chalky deposits in the header tank as the water level in the tank has been much higher and therefore the rain water system has been working correctly as stated by Cath Hassell in her recent report on the 24th July 06.

Billy Eastman

August 8th 06

Appendix D- Tenants survey

Questionnaire

Summary of results- Evaluation of the building

Summary of results -Environmental behavior

Boatemah Walk development survey 2006

UCL

This questionnaire is part of a study carried out by Lidia Johansen- Vargas, an MSc student on the Environmental Design and Engineering Course at the Bartlett Graduate school at UCL. The aim of this questionnaire is to find out your perception of comfort in your living space and which factors can affect the performance of passive and active systems installed in the building. Your answers will be anonymous.

1 Can you tell us how many people of each age range live here? (enter numbers)

0 - 5 years	6 - 15 years	16 - 64 years	Over 65 years

2 On a typical weekday is your flat occupied during these times? (1=occupied, 0= empty)

Midnight - 7am	7am-Lunchtime	Lunchtime - 5 pm	5pm - 9pm	9pm to Midnight

3 Please rate how warm or cold your flat is on average

Hot	Warm	OK	Cool	Cold

4 Please rate the typical humidity in your flat

Very Damp	Damp	OK	Dry	very Dry

5 Please rate the typical daylight quality in your flat

very good	good	OK	A bit dark	very dark

6 Please rate the general air quality in your flat

very good	good	OK	poor	very poor

7 Please rate your perception of pollution coming from outside

very strong	strong	tolerable	mild	no pollution

8 Please rate the external noise levels you perceive while in your flat during daytime

very strong	strong	tolerable	mild	no noise

9 Please rate the external noise levels you percieve while in your flat during nighttime

very strong	strong	tolerable	mild	no noise

10 Please rate the quality of lighting in the stairwells

Too bright	bright	adequate	dim	too dim

11 Please rate the ease in controling the heating levels to your liking?

Easy	OK	Difficult

12 On a typical cold day, during which hours do you have the heating on? (1=on, 0=off)

Midnight - 7am	7am-Lunchtime	Lunchtime - 5 pm	5pm - 9pm	9pm to Midnight

13 In cold weather: How often do you open the windows?

never	rarely	occasionally	often	always

14 In cold weather, do you wear more clothes inside your home than in warm weather?

never	rarely	occasionally	often	always

15 In cold weather, how warm do you like to have the house?

More than 30 C	26 to 29C	23 to 26 C	20 to 23C	Less than 20 C

16 In cold weather, do you lower the temperaure at night?

never	rarely	occasionally	often	always

17 **Do you put a lid on the pot when cooking?**

never	rarely	occasionally	often	always

18 **When leaving a room unoccupied, do you switch the lights off?**

never	rarely	occasionally	often	always

19 **Do you switch the TV off with a button instead of using the remote control?**

never	rarely	occasionally	often	always

20 **How many hours a week in average do you spend ironing?**

enter number

21 **How many hours a week in average do you spend using the hairdryer?**

enter number

22 **Are your electric appliances energy efficient (A rated)?**

All of them	Some of them	I don't know	None of them

23 **When you use the washing machine, do you ensure it is fully loaded?**

never	rarely	occasionally	often	always

24 **In average, how many times a week do you use your washing machine?**

enter number

25 **When washing dishes, do you use cold or warm water?**

warm	cold

26 **When washing dishes, do you do it under running water?**

never	rarely	occasionally	often	always

27 **How many times a week do you fill the bath?**

enter number

28 **How many times a week is the shower used?**

enter number

29 **In average, how long do people in your household take to shower?**

.+ than 30 min	20 to 30 min	10 to 20 min	5 to 10 min	Less than 5 min

30 **The toilets flush with rain water, have you noticed any problem with the supply?**

never	rarely	occasionally	often	always

31 **Please rate your perception about the use of rainwater for toilet flushing**

Great	OK	Pointless

32 **Please rate the quality of the water used to flush the toilets**

dirty	just right

33 **As a water saving measure, the toilets are equipped with 2 options of water discharge. Please rate your perception about this:**

Great	OK	Pointless

34 **The solar panels on the roof of this building provide free electricity for some residents Please rate your perception about this:**

Great	OK	Pointless

35 Since moving into your flat how would you rate your energy use compared to your previous flat?

Much less	Less	About the same	More	Much more

36 Overall how do you rate the condition in this building for your well being and comfort?

Excellent	Good	OK	poor	very poor

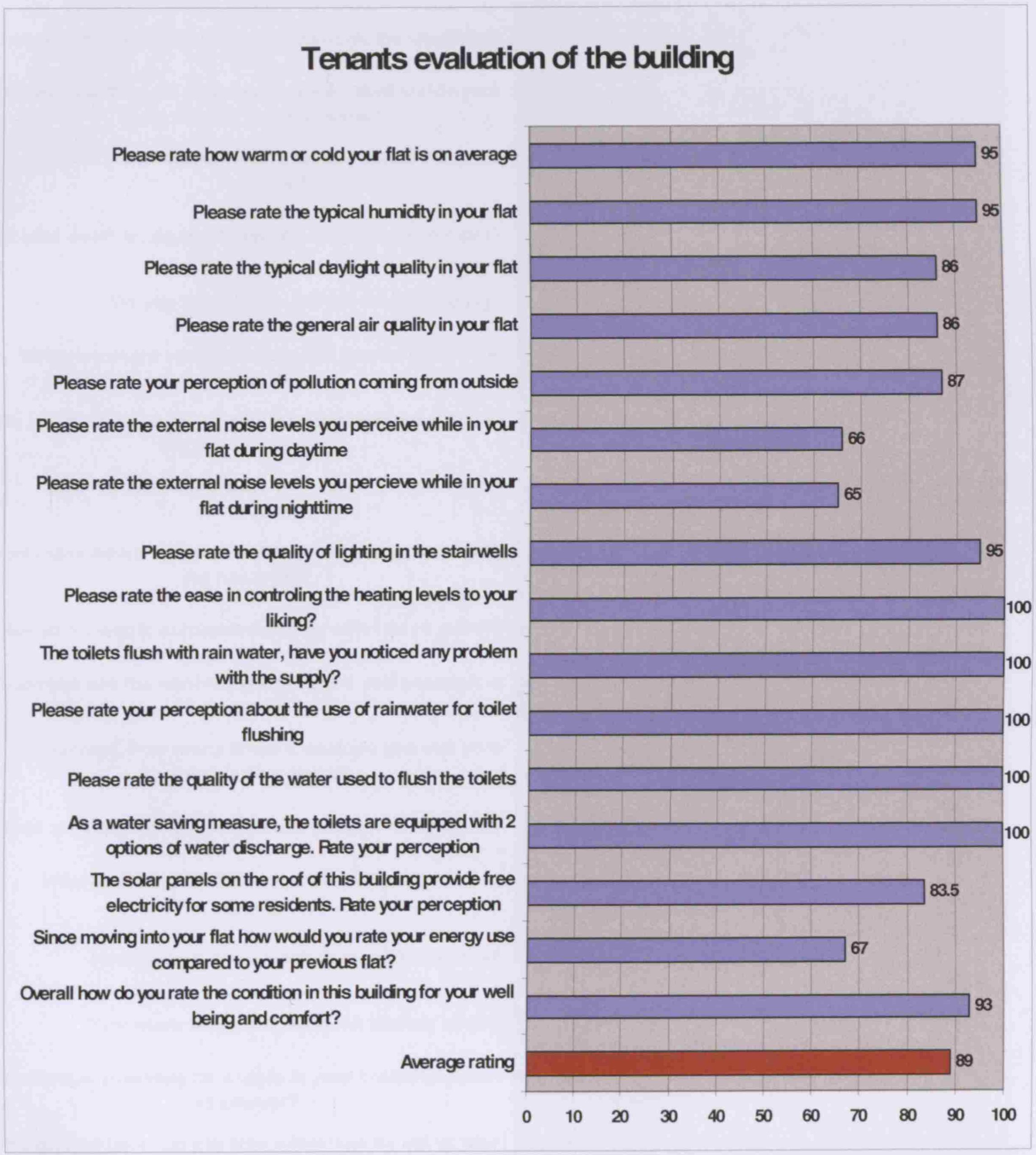
37 For ground floor tenants only.
The solar panels in the roof produce free electricity when there is daylight
Do you take advantage by using your electric appliances during daylight hours?
(iron, vacuum cleaner, washing machine, dishwasher, microwave oven)

never	occasionally	always

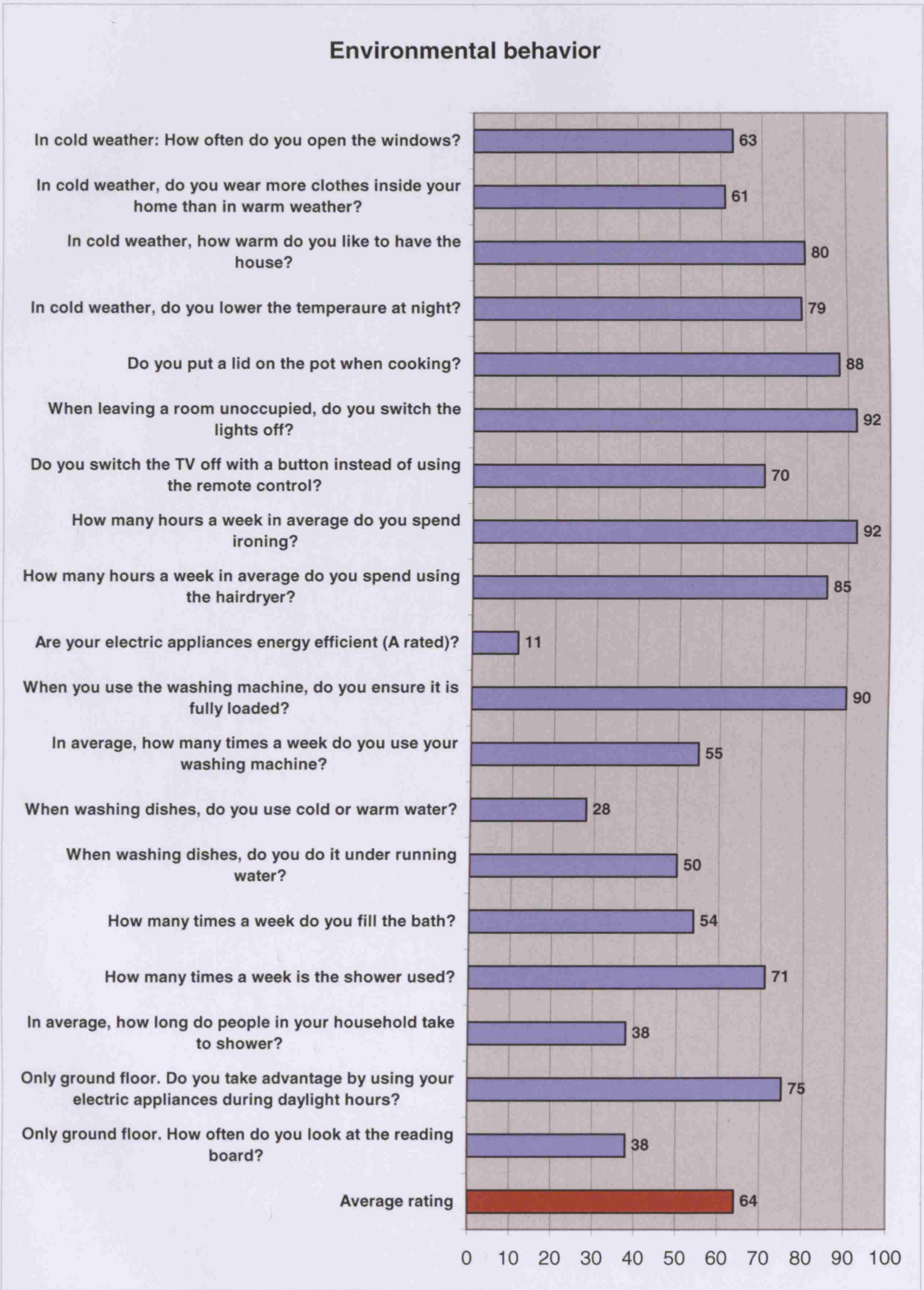
38 For ground floor tenants only.
There is a meter showing how much electricity is produced by these panels
How often do you look at this?

never	ocassionally	always

39 Is there any additional comment you would like to make?



Tenants evaluation of the building
Please rate how warm or cold your flat is on average
95
Please rate the typical humidity in your flat
95
Please rate the typical daylight quality in your flat
86
Please rate the general air quality in your flat
86
Please rate your perception of pollution coming from outside
87
Please rate the external noise levels you perceive while in your flat during daytime
66
Please rate the external noise levels you percieve while in your flat during nighttime
65
Please rate the quality of lighting in the stairwells
95
Please rate the ease in controling the heating levels to your liking?
100
The toilets flush with rain water, have you noticed any problem with the supply?
100
Please rate your perception about the use of rainwater for toilet flushing
100
Please rate the quality of the water used to flush the toilets
100
As a water saving measure, the toilets are equipped with 2 options of water discharge. Rate your perception
100
The solar panels on the roof of this building provide free electricity for some residents. Rate your perception
83.5
Since moving into your flat how would you rate your energy use compared to your previous flat?
67
Overall how do you rate the condition in this building for your well being and comfort?
93
Average rating
89
0
10
20
30
40
50
60
70
80
90
100



Environmental behavior
In cold weather: How often do you open the windows?
63
In cold weather, do you wear more clothes inside your home than in warm weather?
61
In cold weather, how warm do you like to have the house?
80
In cold weather, do you lower the temperaure at night?
79
Do you put a lid on the pot when cooking?
88
When leaving a room unoccupied, do you switch the lights off?
92
Do you switch the TV off with a button instead of using the remote control?
70
How many hours a week in average do you spend ironing?
92
How many hours a week in average do you spend using the hairdryer?
85
Are your electric appliances energy efficient (A rated)?
11
When you use the washing machine, do you ensure it is fully loaded?
90
In average, how many times a week do you use your washing machine?
55
When washing dishes, do you use cold or warm water?
28
When washing dishes, do you do it under running water?
50
How many times a week do you fill the bath?
54
How many times a week is the shower used?
71
In average, how long do people in your household take to shower?
38
Only ground floor. Do you take advantage by using your electric appliances during daylight hours?
75
Only ground floor. How often do you look at the reading board?
38
Average rating
64
0 10 20 30 40 50 60 70 80 90 100